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SYNOPTIC ANALYSES, 5-, 2-, AND 0.4-MILLIBAR SURFACES FOR JANUARY 1972 THROUGH JUNE 1973

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

Data from meteorological rocketsonde and satellite radiance measurements have been employed to analyze a series of high-altitude synoptic charts. The methods employed for processing the various types of data and the analysis procedure used are described.

Broad-scale analyses for the Northern Hemisphere 5-, 2-, and 0.4-mb surfaces are presented weekly from September through April and monthly from May through August during the period January 1972 through June 1973. A brief discussion of the height and temperature fields is also given. Circulation and temperature changes associated with a minor stratospheric warming in January and February 1972 and a major stratospheric warming in January and February 1973 are among the discussion items.

INTRODUCTION

This report is the sixth in a series of constant-pressure charts for the upper stratosphere and lower mesosphere. Charts for 1964-68 (refs. 1, 2, 3, 4, 5) were analyzed at weekly intervals (ref. 6) and were based on meteorological rocketsonde and very high level rawinsonde data obtained over Northern America and adjacent ocean areas (ref. 7).

Since 1972 (pursuant to a bilateral agreement between the United States and the Soviet Union), data from meteorological rocketsonde stations of the Western and Eastern Meridional Networks have been exchanged on a regular basis (ref. 8). Recently available data from Heiss Island and Volgograd (Soviet Union) and Thumba (India) together with other data from Ryori (Japan) and El Arenosillo (Spain) have made it possible to extend the analyses over Eurasia. Figure 9 shows the locations of the 20 meteorological rocket launch sites over the Northern Hemisphere for which data were available. Because of improvements in the methods of routine transmission and receipt of rocketsonde data by the teletypewriter-coded ROCOB messages, charts could be constructed from these data rather than delaying until publication of the rocketsonde observations.

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[1]Personnel actively engaged in this report were Manager, F. Finger; Coordinator and Analyst, M. E. Gelman; Analysts, R. Nagatani and J. Laver; Research Consultants, R. S. Quiroz and A. J. Miller; and data processing, D. Griffith.

Recently, data from satellite vertical temperature sounding instruments also have become available (see section on satellite data, below). These remote observations, when used together with the expanded number of in situ observations, provide for greatly improved data coverage over the entire hemisphere.

The present series of analyses at the 5-, 2-, and 0.4-mb surfaces (approx 36, 42, and 55 km, respectively) represent the broad-scale synoptic conditions over the Northern Hemisphere on each Wednesday during January 1972 through June 1973. Charts are presented weekly during the winter months (October through March) and transition periods (April and September) and monthly during summer (May through August). The monthly frequency appears sufficient to depict the slow, broad-scale changes that occur in summer. Small-scale time and space changes and planetary waves of small amplitude (ref. 9) are observed during summer, but the horizontal resolution of the analyses in most areas would not be sufficient to depict them. During winter and the transition periods, however, larger changes are evident from one week to the next. Sometimes, large changes occur within a day or two, and these may be inferred from the sequence of up to three observations plotted at each rocket station. Thus the user may expand the utility of the weekly charts by noting any large changes during the week in plotted temperature or wind direction. These changes frequently indicate movements of the synoptic systems depicted in the Wednesday charts.

Despite the omission of small-scale details, the maps are very useful for a number of applications such as determining the trajectory of constant-level balloons, relating variations in infrasound propagation to circula-ation changes, and providing a data base for evaluating environmental effects on aerospace vehicles. In addition, users have pointed to the increasing utility of these maps in studies of stratospheric-ionospheric interaction, for verification of the performance of numerical circulation models, and in various other research efforts.

PROCESSING OF ROCKETSONDE DATA

Temperature, height and wind information derived from routine meteorological rocketsonde observations comprised the basic data for analyses at the 5-, 2-, and 0.4-mb levels. Rocketsonde information used for this project were obtained from teletype coded ROCOB messages (WMO code FM39.E ROCOB and FM40.E ROCOB ship). These data were usually transmitted from each rocketsonde station within one day of the observation. Data from Heiss Island, Volgograd and Thumba (The three stations in the Northern Hemisphere associated with the Eastern Meridional Network), were available in ROCOB format within one week of observation time.

The ROCOB message provides data in the form of temperature and wind versus geometric height. The vertical coordinate must be transformed from height to pressure so that temperature, height, and wind information may be extracted at the desired levels.

The procedure for calculating pressure and extracting the required information for the 5-, 2-, and 0.4-mb levels was as follows:

a. Pressure was calculated at each ROCOB reported level by a computer program which integrated the hydrostatic equation starting at a base level

near 50 mb. Temperature and height data obtained from a nearby rawinsonde station were used as the reference-level data. The geopotential heights and temperatures at the 5-, 2-, and 0.4-mb levels were interpolated in this computer program.

b. Wind direction and wind speed (in knots) were interpolated manually at the calculated height of each analysis level. When temperature data were not available for a particular sounding, the wind information was extracted at individually estimated heights of the 5-, 2-, and 0.4-mb levels.

c. Time-height diagrams were plotted for each of the 20 rocketsonde stations. The temperature and wind information on these diagrams provided valuable verification of the sequence of meteorological changes. Erroneous or questionable data could be quickly isolated in this manner.

d. From the wind information plotted on the time-height diagrams, thermal winds were determined for approximately 6-km layers surrounding each analysis level. A somewhat subjective approach was necessary because the calculations were performed manually and there were sometimes rapid wind oscillations with height. Usually an unambiguous direction for the thermal wind could be determined.

e. Special adjustments were made to the 0.4-mb data because ROCOB data normally contain uncorrected temperatures. Thermistor rocket soundings generally require correction above about 40 km. Temperature adjustment values are given in Table 1a, b, and the basis for these adjustements is described below.

(i) For the U.S. Datasonde instrument used at the majority of Northern Hemisphere stations, corrections have been derived by theoretical and laboratory methods (ref. 10). The corrections account for aerodynamic heating (which depends mainly on the fall velocity of the sensor), thermal lag, emitted and absorbed radiation, and electrical heating. Precise corrections based on these factors vary from sounding to sounding and can only be calculated from auxiliary rocketsonde information. For our purposes, it was deemed satisfactory to derive a set of corrections based on average sensor fall velocities and for sunlight and darkness conditions (Table 1c).

(ii) Application of the average corrections at 0.4 mb is not sufficient to achieve compatibility between U.S. and U.S.S.R. ROCOB temperatures. Indirect comparisons between U.S.S.R. and U.S. uncorrected rocketsonde temperatures indicate large differences increasing with height above 45 km. An example of such an indirect comparison is shown in Figure 1 for the U.S. rocketsonde station at Fort Sherman, C.Z., and Thumba, where the U.S.S.R. rocketsonde is used. Although these stations are geographically distant, they are within one degree of the same latitude circle, and there is no evidence (satellite data, thermal winds etc.) supporting the existence of a real standing wave in temperature throughout the year of the magnitude inferred from the data from these stations. Comparisons were also made for the U.S. station at Thule and the U.S.S.R. station at Heiss Island, both at latitudes near 80°N, with results strikingly consistent with those in Figure 1.

TABLE I. - THEORETICAL CORRECTIONS AND EMPIRICAL TEMPERATURE ADJUSTMENTS (°C) DERIVED TO OBTAIN COMPATIBILITY BETWEEN U.S. AND U.S.S.R. ROCKETSONDE MEASUREMENTS

	(a)		(b)	(c)		(d)	(e)
KM	U.S. Adjustment Day	U.S. Adjustment Night	U.S.S.R. Adjustment	Average Theoretical U.S. Correction Day	Average Theoretical U.S. Correction Night	U.S.S.R. Minus U.S.	Empirical U.S. Difference Night Minus Day
58	-16	-4	9	-6.0	-3.6	-25	-12
55	-8	-2	7	-4.2	-2.4	-15	-6
50	-5	-1	2	-2.5	-1.4	-7	-4

Although differences between the U.S. and U.S.S.R. temperature data (shown in Table 1d) were derived indirectly, there apears to be little doubt that temperatures from the U.S.S.R. observations are significantly lower than those reported by the U.S. instrument. Correction of the U.S. reports by values shown in Table 1c would reduce the incompatibility only partially.

Meanwhile, it is known that very large corrections are applied by the Soviet scientists in order to compensate for very large fall velocities. Thus the residual uncertainty in their corrected temperatures near 55 km may possibly exceed the uncertainty in corrected U.S. soundings.

(iii) There is a complicating factor when trying to rationalize the seeming incompatibility between U.S. and U.S.S.R. temperature data. This factor is the temperature change brought on by the real diurnal temperature variation of the atmosphere. If all rocket observations were taken at the same local time, this would not pose any problems. However, The U.S.S.R. rockets are launched primarily during nighttime hours while U.S. rockets normally are launched near noon. Thus, the amplitude and phase of the diurnal temperature oscillation are undoubtedly an important factor. In order that a consistency in time be maintained in the analyses, adjustments must include this factor. The adjustments for U.S. instruments are based on an experiment held at Wallops Island, Virginia in October and November 1972. A series of mid afternoon, pre-sunset and post-sunset observations (uncorrected) indicate the day-night differences shown in Table 1e. Real diurnal temperature change as well as instrumental radiation error are the principal factors for these differences. Thus a total adjustment to the U.S. measurements taken during the day to reduce them to ambient nighttime values is the sum of the empirical day-night difference and the theoretical nighttime correction. However, even this total adjustment (Table 1a) to the U.S. measurements does not account for the entire observed U.S.—U.S.S.R. temperature differences. The remaining portion has been assigned as an adjustment to the U.S.S.R. data (Table 1b). All adjustments to U.S. reports result in temperatures <u>lower</u> than reported, while U.S.S.R. adjustments result in <u>higher</u> than reported temperatures. The calculated 0.4-mb heights from U.S. instruments were lowered by 200 gpm. This represents the approximate integrated effect of the temperature measurement being too high from 0C degrees at 2 mb to 8C degrees at 0.4 mb. The 0.4-mb heights from U.S.S.R. instruments were raised by approximately 100 gpm.

The rocketsonde data, temperature (C°), height (geopotential meters), wind direction and speed (knots), were plotted on a polar stereographic map base. On the charts presented for publication three observations closest to Wednesday are shown when available for each station. Reported heights and calculated thermal winds have been omitted for the sake of legibility. The station model chart (Fig. 9) illustrates the symbols used to distinguish data obtained on Wednesdays from off-time data.

SATELLITE DATA

For January to April 1972, Nimbus 4 Satellite Infrared Spectrometer (SIRS) and Selective Chopper Radiometer (SCR) (ref. 11) data were used for the analyses at 5, 2, and 0.4 mb. Nimbus 5 SCR (ref. 12) and NOAA 2 Vertical Temperature Profile Radiometer (VTPR) (ref. 13) data were used for the 1973 analyses. The method of using the remotely sensed temperature information for determining stratospheric thickness was developed by Quiroz and Gelman (ref. 14). In brief, the radiant energy sensed by a satellite instrument in any spectral band is representative of the weighted temperature from a substantial layer in the atmosphere. Single channel relationships were derived relating satellite measured radiances and the radiosonde-rocketsonde thickness (or mean temperature) between the 100- to 5-mb, 100- to 2-mb, and 10- to 0.4-mb levels. These thickness relationships are shown in Figure 2a. A table was then constructed relating observed radiance with thickness values at 320 meter intervals for each of these atmospheric layers. Using this table, the radiance map containing 24 hours of satellite data was analyzed for the appropriate radiance interval, with the radiance lines then being converted to thickness values. This thickness field was then graphically added to the height field given by the objectively-analyzed chart produced at the National Meteorological Center (ref. 15) for the lower level (100 mb for the 5- and 2-mb charts, and 10 mb for the 0.4-mb charts). The resultant field was used as a first guess for the 5-, 2-, and 0.4-mb height chart.

Relationships between radiance and temperature at 5, 2, and 0.4 mb were also sought. A weaker physical relationship exists between radiance and the temperature at any particular level than exists between radiance and the mean layer temperature or thickness. However, it was found that SCR channel B and SCR channel A specified the temperature at 5 and 2 mb to a good approximation (RMS error, approximately 8°C). These relationships are shown in Figure 2b. The temperature patterns obtained by relabeling the appropriate radiance charts were then used as a first guess in deriving the 5- and 2-mb temperature analyses.

ANALYSIS PROCEDURE

The analysis procedure consisted of obtaining first guess temperature and height fields and then adjusting these fields to conform with the rocketsonde wind, height, temperature and thermal wind information. When satellite data were available, first guess fields were obtained using the methods discussed in the previous section. If satellite data were not available, conventional techniques were used to construct the temperature field, first at 5 mb; then differential analysis methods were used to obtain the height fields. Once the 5-mb fields were completed, the fields at 2 mb, then at 0.4 mb were built in a similar manner.

The analysis system consisted of the following steps:

a. Isotherms were derived using as primary information the plotted rocketsonde temperatures. Data acquired for the entire week were examined to determine the synoptic changes that took place during the week. Thus, conditions pertaining to Wednesday, the analysis day, were deduced. The SCR radiance data, when available, were especially useful in providing a first approximation to the temperature fields. Computed thermal winds were

very useful in determining horizontal temperature gradients and the relative location of warm and cold areas. Time-height sections of temperature were consulted as a further aid in deriving the isotherms.

b. When satellite data were not available, a first guess height field was derived by differential analysis. A mean temperature field representative of the layer between the previously analyzed lower surface and the slected surface was derived graphically. This mean field represents a geopotential thickness which, when added to the lower level height field, yields a smooth, conservative first approximation to the contour pattern at the upper surface.

c. Reported winds and computed heights for individual stations were then used to adjust the first approximation of the contour field, assuming geostrophic flow. Winds were accorded the highest priority for this adjustment. When large adjustments were made to the contour field, the temperature field was then adjusted to maintain hydrostatic consistency.

d. The analyses were reviewed for vertical and temporal consistency. For example, circulation centers, ridges, and troughs were examined with the aid of all available data to verify vertical slope and movement with time. Time-height sections and height-change charts were especially useful for those purposes.

The above procedures appear to produce excellent results at 5 mb and 2 mb, and were successfully applied to obtain the 0.4-mb charts. Generally only slight adjustments of the first-approximation height fields were necessary at the 5- and 2-mb levels. However, rather formidable analysis problems were evident at the 0.4-mb level.

One problem arises from the apparent intersection of the stratopause with the 0.4-mb level. Because the normal stratospheric temperature inversion ceases at the stratopause level, the graphical method for obtaining mean temperature, which depends on the existence of a linear profile, is no longer valid. Large adjustments must be made, especially at lower latitudes, in the graphically derived height field to conform with the computed height at each station. This difficulty is largely overcome when satellite data are available for use in deriving first guess fields.

Another difficulty was the apparent occurrence of large day-to-day temperature changes, at times exceeding 10°C (ref. 16), and persistent oscillations in many wind profiles. In most cases, deviations of reported temperatures and winds from one another could be accounted for by identifiable rapid large-scale synoptic changes. Sometimes rocketsonde reports within a few hours of each other at a single station exhibited temperature changes of 5° to 7°C over a limited height interval near the stratopause. It has been shown that such small-scale subsynoptic changes are possible at these levels (ref. 17). Thus, some intermediate value was chosen for analysis to represent the value on the analysis day. Occasionally, it was impossible to make a reasonable reconciliation of reported station values.

Although careful consideration of high-level data allows a broadscale depiction of circulation patterns up to 0.4 mb, the sparsity of reports requires increasing subjectivity as the analysis proceeds to this level. The justification for some analyses depends on the interpretation of the limited amount of data in such a way as to portray a coherent sequency of synoptic events. In spite of these factors, surprisingly

little alteration in the principal features of the circulation and temperature distribution shown in the final analysis can be made without inordinately violating some of the data. In general the contours and isotherms depicted are felt to be good approximations to the flow and temperature patterns at this level. Even so, the same degree of accuracy that is found customarily in the analysis of charts at lower levels should not be expected.

A contour interval of 320 geopotential meters was used throughout the year. In addition, intermediate dashed contours were used to outline areas of relatively weak gradient, especially during the spring and fall changeover periods. Isotherms were drawn and labeled at 5°C intervals.

DISCUSSION OF THE JANUARY 1972 - JUNE 1973 CIRCULATION

The temperature and circulation patterns during January and February 1972 are of considerable interest because of the large scale changes associated with warmings in the upper stratosphere. However, these stratospheric warming events were not major warmings with respect to their influence on the circulation of the lower stratosphere.

In the first week of January, a significant warm area was apparent over much of the Northern Hemisphere, extending from eastern North America at mid-latitudes and spiralling around Eurasia northeastward to eastern Siberia. The artic cold center became elongated at 5 mb and developed into a double center at 2 mb, while warm air prevailed over the polar area at 0.4 mb. Strong temperature gradients characterized the situation at each level; as much thermal contrast was evident longitudinally as there was with latitude. The height field also reflected a strongly disturbed wintertime situation, with an anticyclonic circulation in the northern Pacific area at 5 mb intensifying and sloping westward at higher levels. The Atlantic anticyclonic circulation remained somewhat less intense than the Pacific feature. The dominant polar vortex was constricted at 5 mb and became elongated between the two anticyclonic circulations at higher levels. Maximum westerly winds approaching 300 knots were reported by rocketsonde stations located in the area associated with the extreme pressure contrasts. The large wind shears associated with these strong winds are further evidence of the intense thermal gradients and the movements and slope with height of the warm-air systems.

During the second week in January a warm area at 2 mb was evident over the polar region in a constricted channel extending from southern Asia and over the Pole to Hudson Bay. This warm area was a persisting feature throughout the next two months at the 2 and 0.4 mb levels, with two intense cold areas located over Europe and the northern Pacific region. The next three weeks remained very strongly disturbed at all levels with the two opposing anticyclones over the Pacific and the Atlantic oscillating both in intensity and position. At the end of January, a region of warm air appeared west of Japan at 5 mb.

On February 9 at 5 mb, the Atlantic anticyclone showed a significant increase in intensity, and the polar vortex became strongly elongated between Atlantic and Pacific anticyclones. The region of warm air which first appeared west of Japan at the end of January made a rapid incursion into the polar region by February 16, accompanied by a marked warming at

5 and 2 mb. The temperature in the warmest areas at 5 mb increased from -20C the previous week to +10C, with temperatures near the Pole increasing about 50C degrees. At 2 mb, the warmest areas increased from -5C to +20C, with polar temperatures increasing about 25C degrees. The changes at 0.4 mb were much less pronounced.

The sudden warm air incursion was followed on February 23 by a correspondingly sudden decrease in intensity of the warm air in the middle stratosphere as the anomaly affected lower levels. The Pacific anticyclone moved to northern Alaska in partial response to the warming at lower levels. On March 1, the polar vortex at 5 mb, split into two cells with the warmest air cooling still further. By March 8, westerly circulation was once again dominant over the northern latitudes, with weaker anticyclonic circulation still evident at middle and low latitudes. Throughout all this activity, however, there was no major reversal of circulation patterns in the lower stratosphere; hence the label of "minor warming" for this period of activity. The temperature gradients became less intense in March as the springtime changeover proceeded. By mid-April, at the 5-mb level, anticyclonic circulation and warm air dominated the polar region, with the reversal in temperature gradient and circulation occurring at higher levels within two weeks. The westerly winds associated with cyclonic circulation were displaced equatorward, with a cellular structure quite evident during this period.

As the summer months approached, the easterly circulation became the dominant feature and the polar anticyclone intensified in response to the solar radiational heating. Maximum temperatures as well as maximum easterly circulation were observed in mid-July. Cooling was evident thereafter in the polar latitudes as perturbations in the easterly circulations developed. A bicellular anticyclonic structure was evident at polar latitudes on the charts for August 16, and by September 5 the developing cyclonic system had formed. As the polar cyclone progressively cooled and intensified, the easterly circulation moved equatorward in the form of cellular ridges. Throughout October, November and December, the polar cyclone deepened, accompanied by increasing westerly winds. Temperatures decreased markedly at 5 and 2 mb during this period but a warm region remained in middle latitudes at 0.4 mb. By December, however, the temperature pattern at the 0.4-mb level was characterized by two cold areas and two warm areas from mid to high latitudes. This pattern persisted for several weeks while the 0.4-mb circulation remained strongly zonal. At low latitudes the subtropical ridge was apparent between 5 degrees and 25 degrees north.

A major stratospheric warming occurred during late January and early February 1973. There were indications of minor pulses as early as December 1972 when the two upper-VTPR channels showed significant radiance increases from December 27 to January 8 with the greatest change beginning in late January (ref. 18). Similarly, the maps which were drawn with the aid of the same radiance data show thermal pulses through the end of January, with a major circulation change occurring at all levels on January 31. Throughout the period leading up to the warming event, anomalously warm air was confined mainly at 2 mb and above in a constricted channel observed over the polar region. Evidence of this is provided by rocketsonde temperatures reported for Heiss Island and Thule. Poker Flat observations on January 16-18 show easterlies only at 0.4 mb while Primrose Lake also showed a report of an easterly wind on January 16. This indicates that the thermal anomaly at that time was strong enough for a weak anticyclonic circulation only at that level. A shift of the Aleutian

anticyclone occurred at 5 mb on January 24, extending easterly circulation into the central U.S. but damping quite rapidly with height.

The period January 24 - 31 was an explosive one. Strong easterlies near the Pole at all three levels on January 31 show that the circulation had already reversed. High temperatures evident upward from 100 mb dominated the maps at 5 and 2 mb. Cooler air at 0.4 mb moving toward the polar regions was overriding the warmer air below. At 5 mb, a ridge of warm air in two cells spiralled from low latitudes starting near Mexico, along the Atlantic into Eurasia, over the Pole and into the north Pacific. A region of cold air remained over the U.S. Similarly, at 2 mb, the ridge of warm air also spiralled in towards the Pole with the ridge at 2 mb lying in more northerly latitudes than the one at 5 mb. The circulation at 0.4 mb consisted of an anticyclone near the Pole with a discontinuous trough made up of three cells of low pressures at mid-latitudes and a ridge of high pressure south of the trough. Cooler air was already moving in towards the Pole at this level.

By mid-February, the polar vortex was re-established at the three analysis levels, with cooler temperatures prevailing and conditions remaining somewhat static for the remainder of the period through mid-April. It is noteworthy that at the 10-mb level, as shown by daily charts (ref. 15), a very weak cyclonic circulation prevailed until early March, when a moderately strong polar vortex was established. Minor thermal pulses were evident at 0.4 mb during March-April, but the heights of the 0.4 mb surface were not significantly altered. By April 18, an anticyclonic circulation appeared over the Atlantic, signifying the start of the changeover period. The anticyclonic circulation had become well established by May 16 at 0.4 mb with indications of a more cellular structure at 5 mb. In June, easterlies were prevalent throughout the layer from 5 to 0.4 mb.

The principal features of the circulation during January 1972 to June 1973 at six representative rocket launch sites may be seen in the time sections (Figs. 3-8) of analyzed height and temperature values extracted from the weekly charts. The annual trend of the height and temperature values is most pronounced at the middle- and high-latitude stations (Figs. 3-6), with the largest range of values occurring in the more northerly stations. Superimposed on this annual trend, characterized by maximum values in summer and minimum values in winter, are various perturbations. The largest of these perturbations occurred during January 1973 and January 1972 and were associated with the stratospheric warmings mentioned above. Smaller scale disturbances associated with movements of the Aleutian anticyclone were seen throughout the winter period. At the tropical station of Antigua, West Indies Associated State (W.I.A.S.), the range of values is very small, with only very minor perturbations affecting the station (Fig. 8). There is a suggestion, however, of a double maximum at the time of the equinoxes associated with the semiannual variation in temperature and wind and related to the seasonal migration of the subtropical anticyclone as seen in the charts. At the subtropical station of White Sands, N. Mex. (Fig. 7), a combination of the major annual variation and the semiannual variation is apparent.

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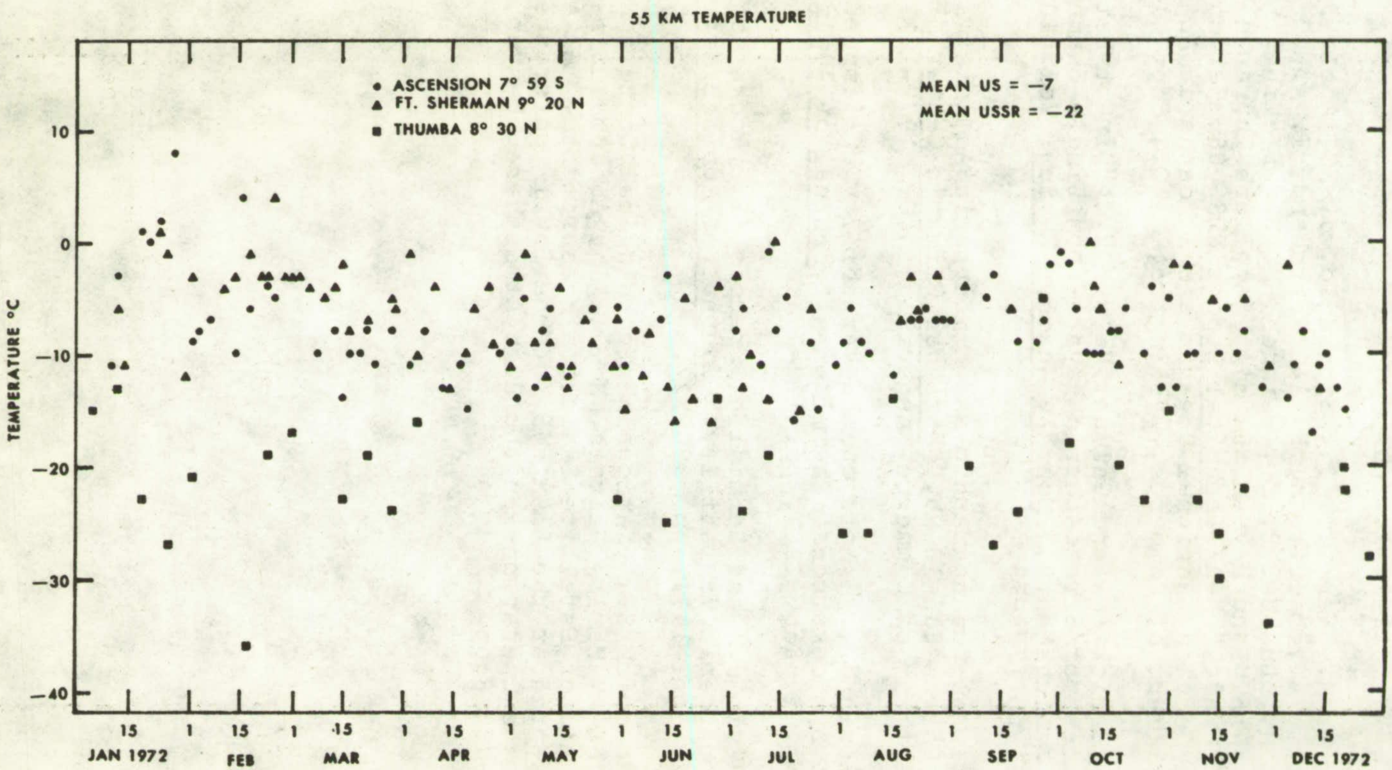


Figure 1. Temperature measured at 55 km during 1972 at Ascension Island, Ft. Sherman, C.Z. and Thumba, India.

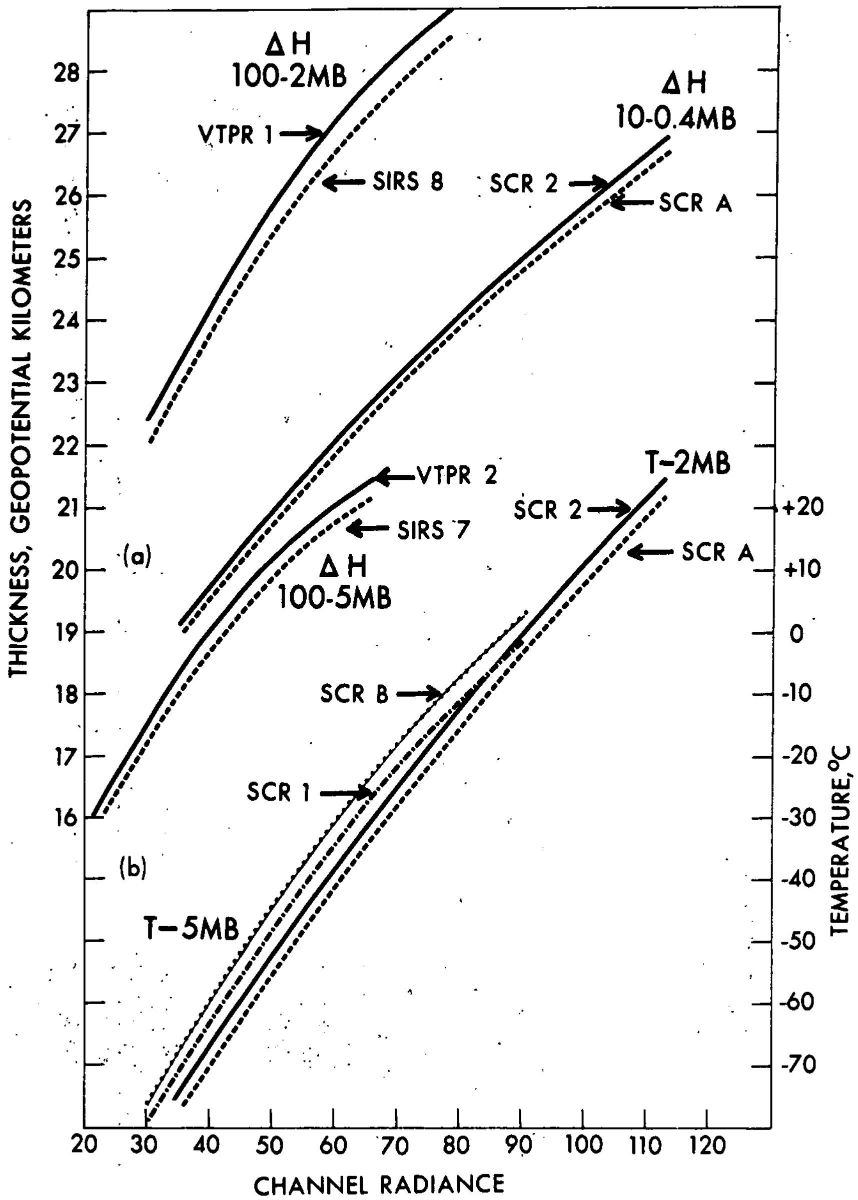


Figure 2. Relationships between satellite-measured radiances and thickness (a); and between radiance and temperature (b). The following relationships are shown: VTPR channel 2 (NOAA 2) and SIRS channel 7 (Nimbus 4) for thickness between 100 to 5 mb; VTPR channel 1 and SIRS channel 8 for thickness between 100 to 2 mb; SCR channel A (Nimbus 4) and SCR channel 2 (Nimbus 5) for thickness between 10 to 0.4 mb; SCR channel A and SCR channel 2 for temperature at 2 mb; and SCR channel A and SCR channel 2 for temperature at 5 mb. Radiance units 10^{-7} J. cm^{-2} . s^{-1} . $(ster)^{-1}$. $(cm^{-1})^{-1}$.

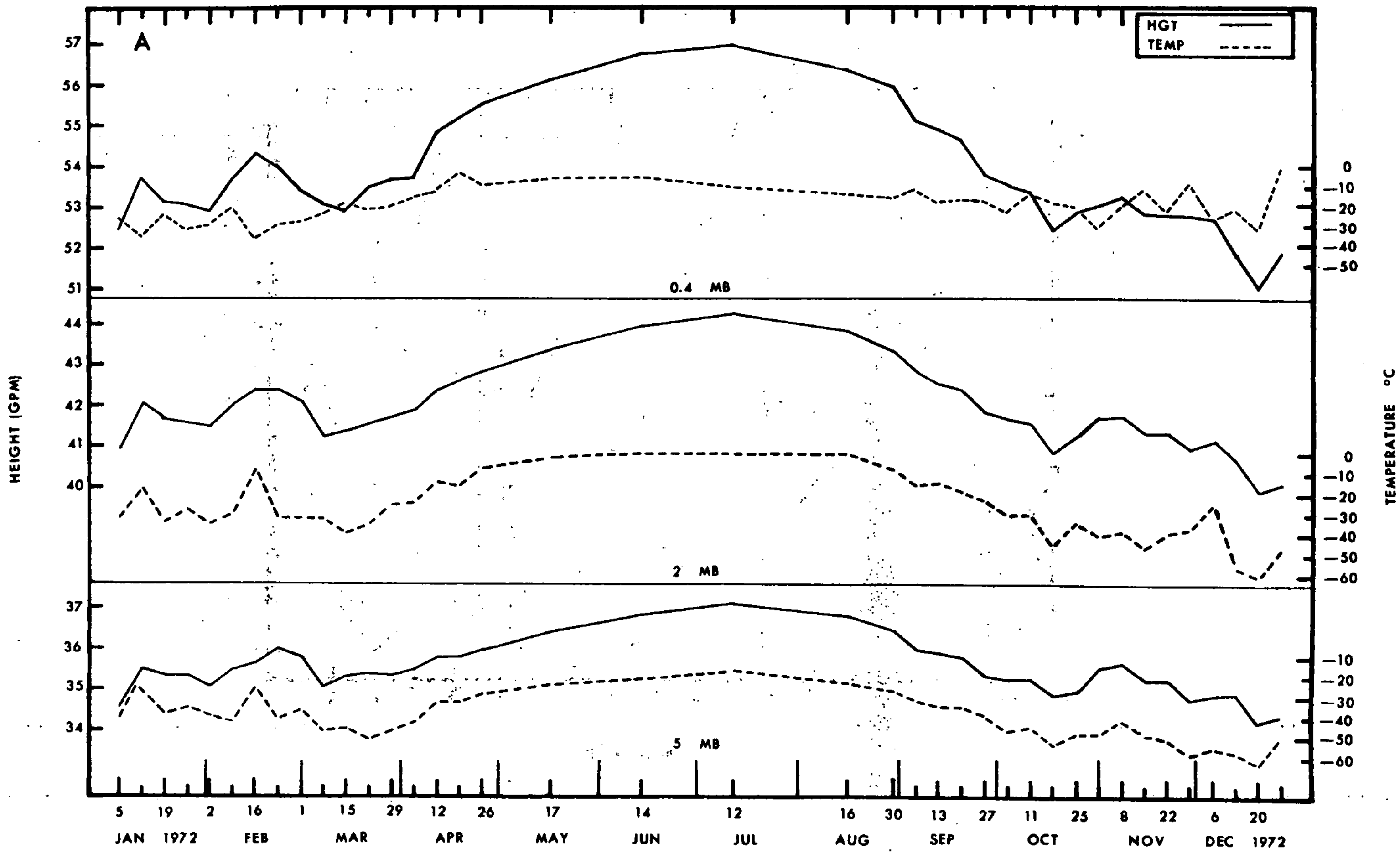


Figure 3a. Poker Flat, Alaska (65°07'N., 147°29'W.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

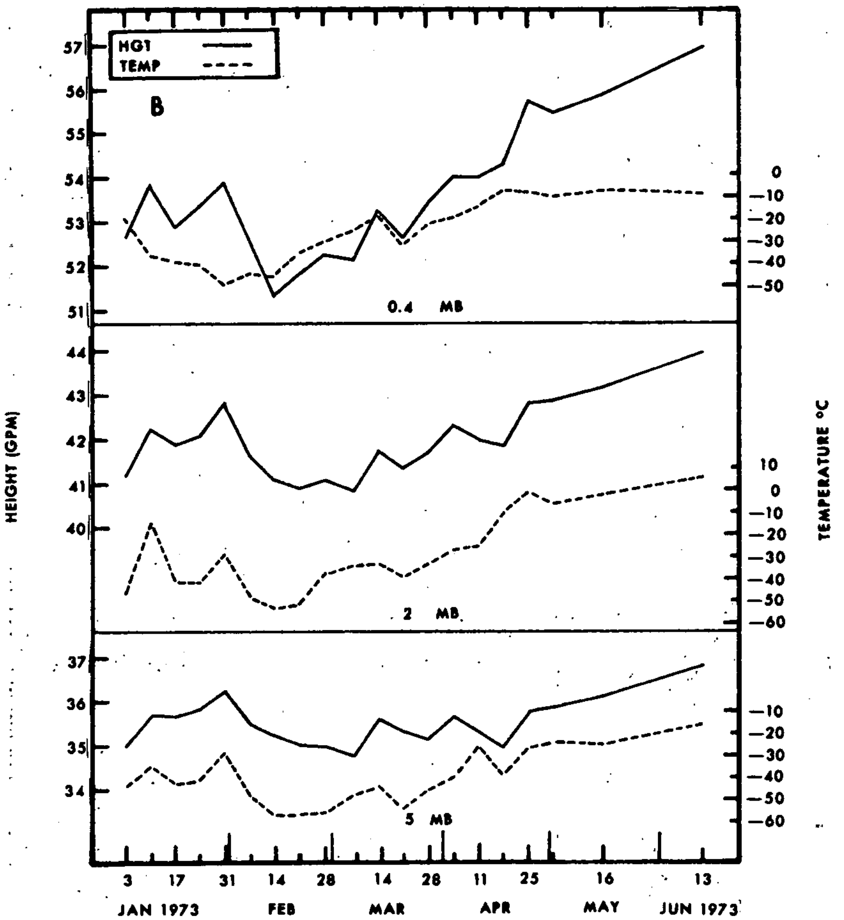


Figure 3b. Same as 3a for January to June 1973.

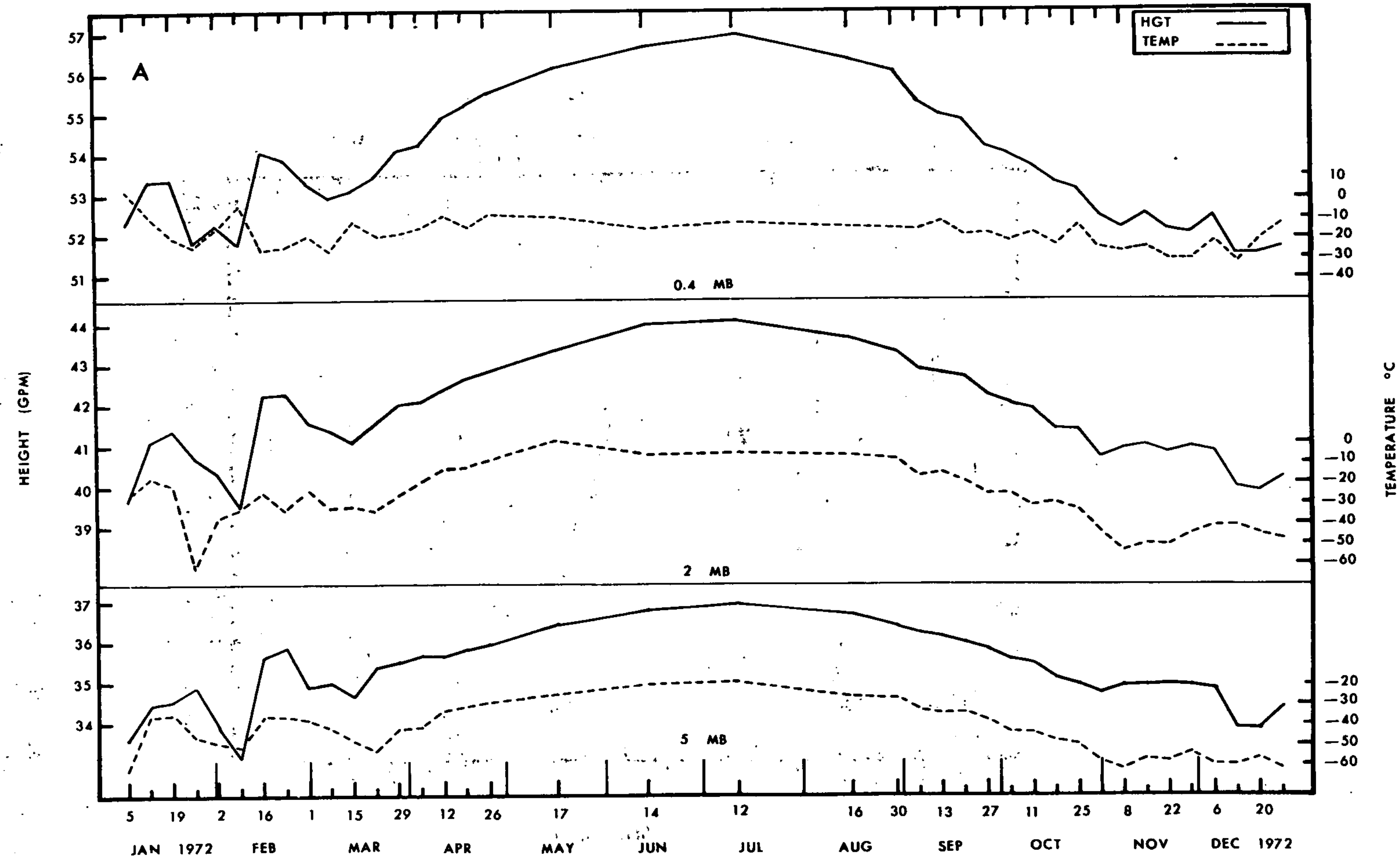


Figure 4a. Fort Churchill, Canada (58°44'N, 93°49'W.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

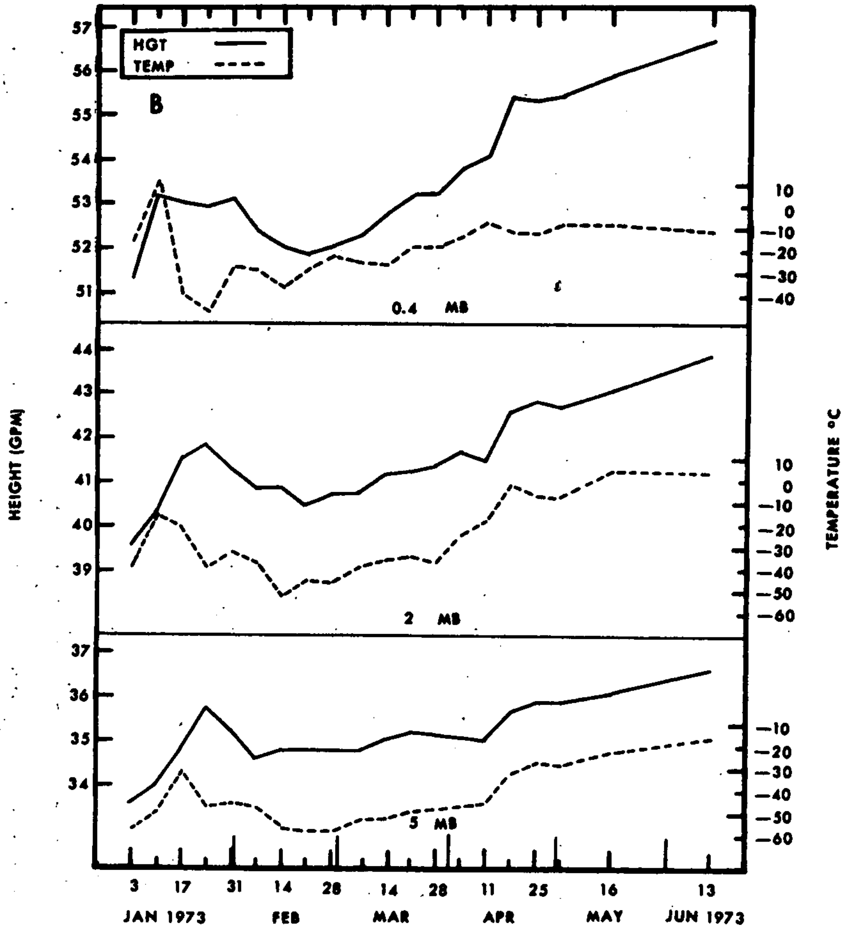


Figure 4b. Same as 4a for January to June 1973.

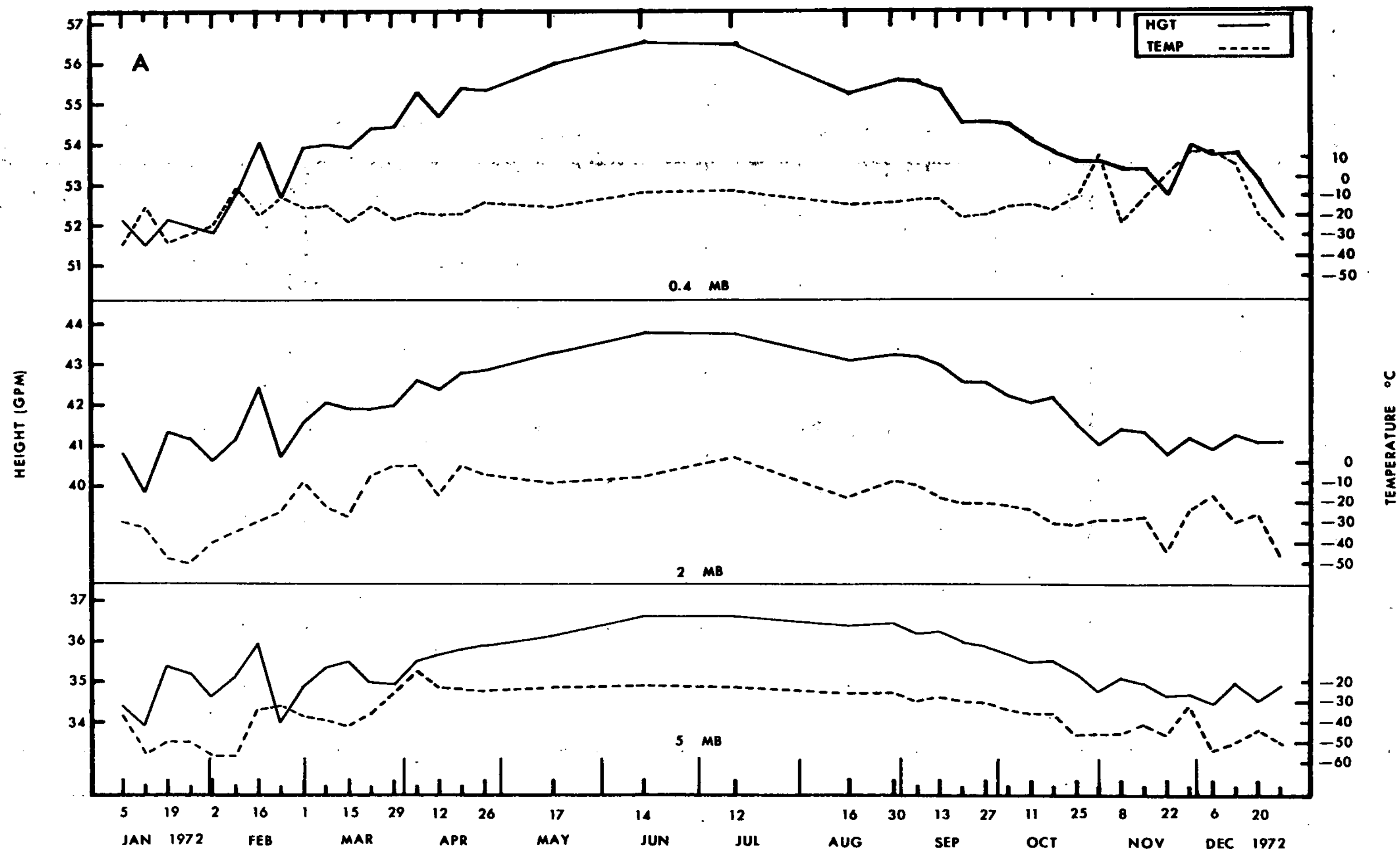


Figure 5a. Volgograd, U.S.S.R. (48°41'N, 44°21'E.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

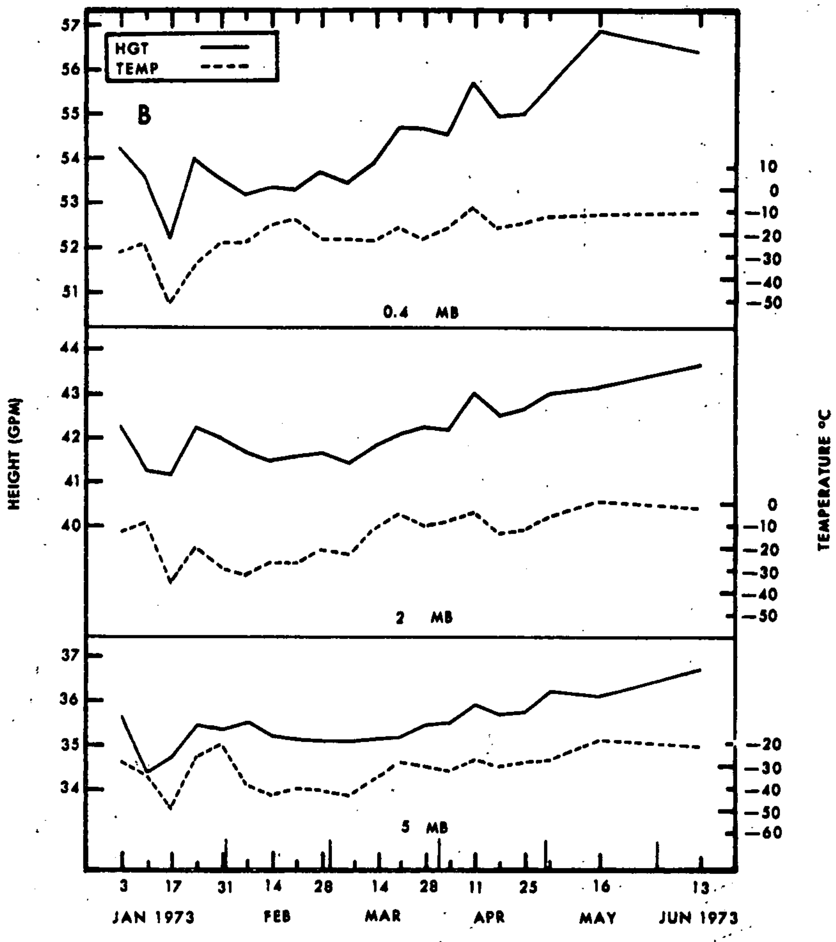


Figure 5b. Same as 5a for January to June 1973.

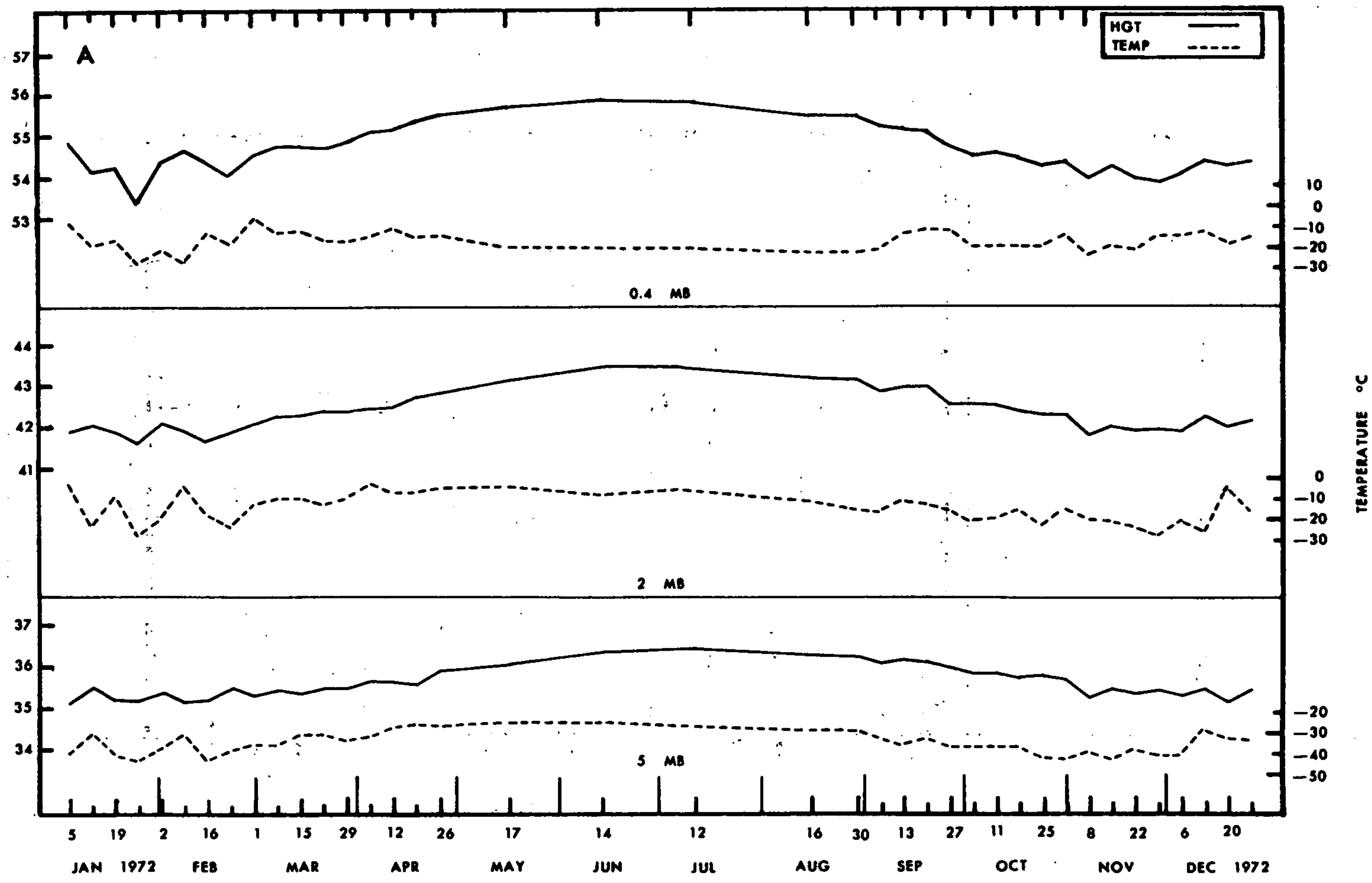


Figure 6a. Wallops Island, Virginia (37°50'N, 75°29'W.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

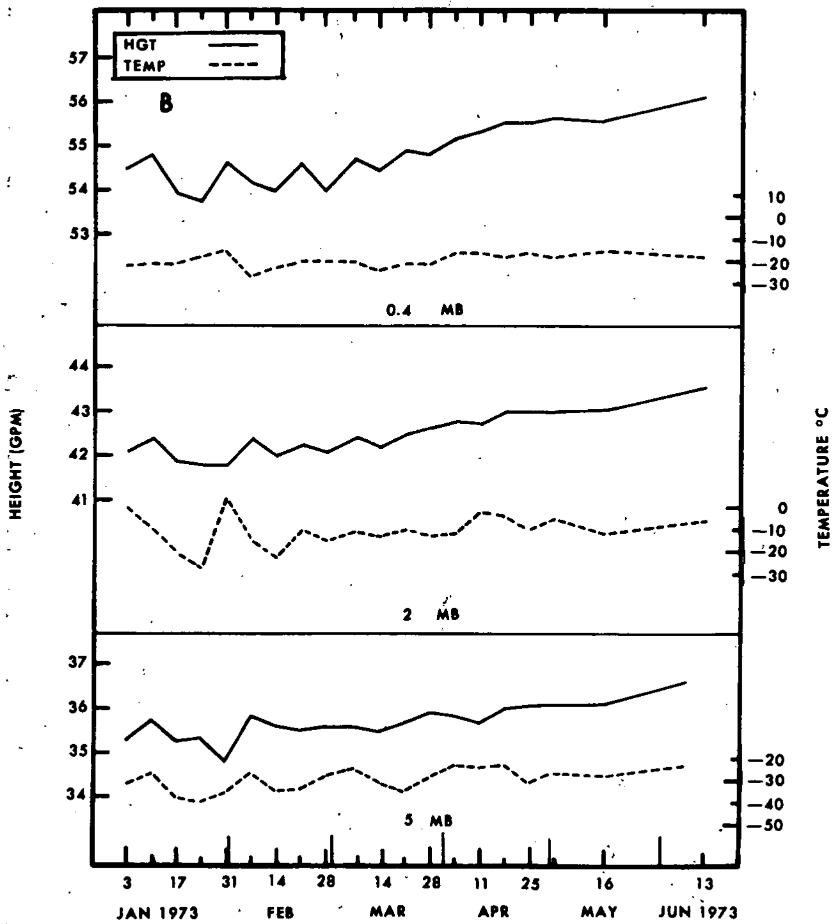


Figure 6b. Same as 6a for January to June 1973.

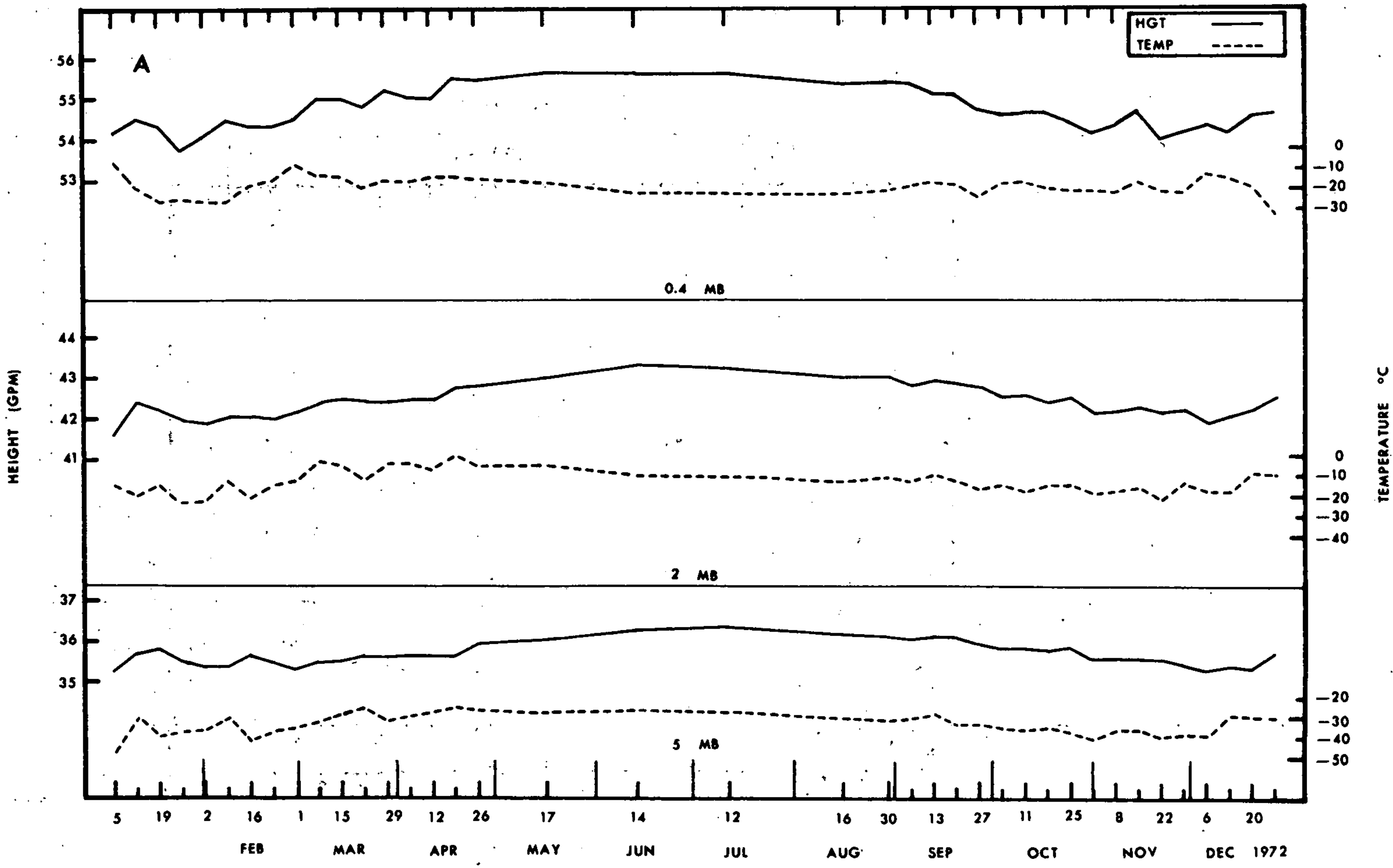


Figure 7a. White Sands, N. Mexico (32°23'N, 106°29'W.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

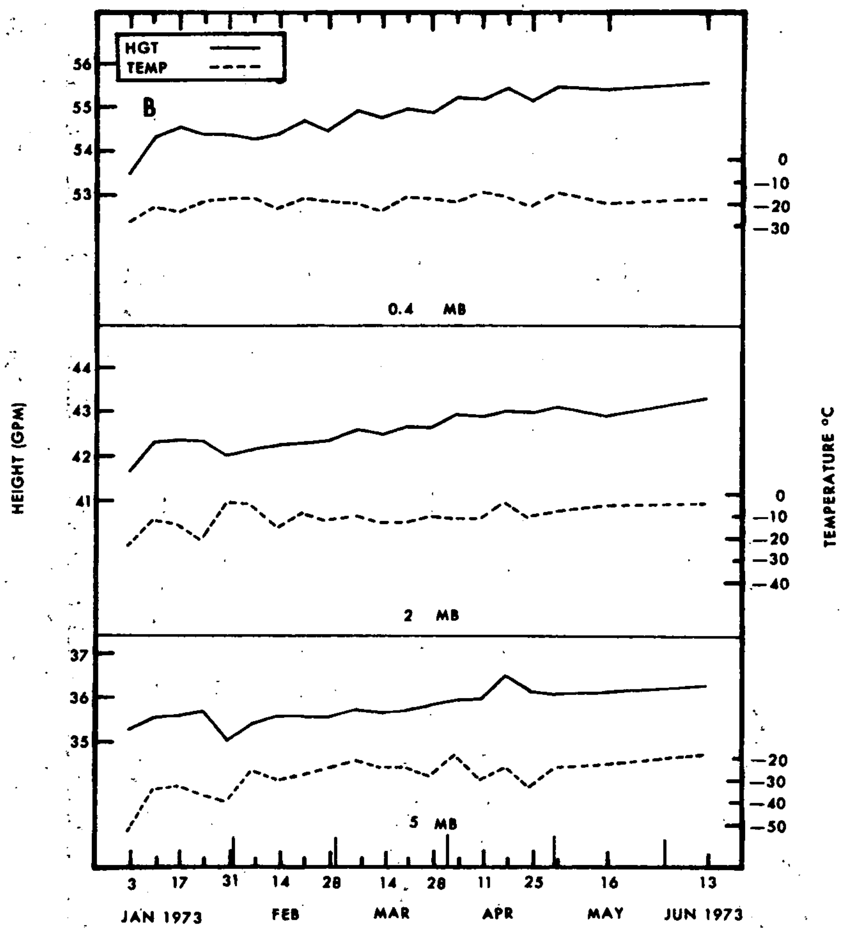


Figure 7b. Same as 7a for January to June 1973.

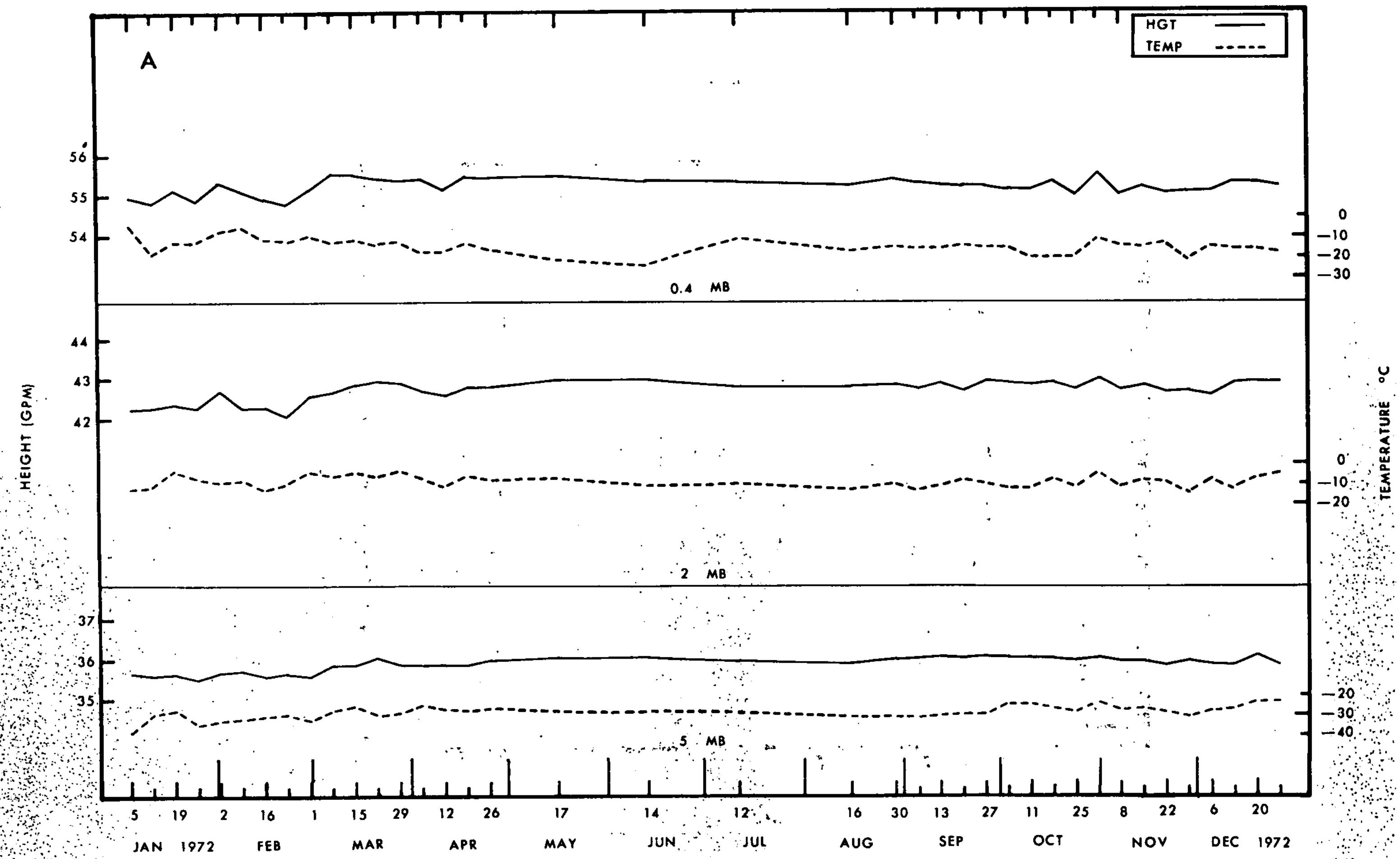


Figure 8a. Antigua, W.I.A.S. (17°08'N, 61°47'W.) analyzed values extracted from the 5-, 2-, and 0.4-mb charts for January to December 1972.

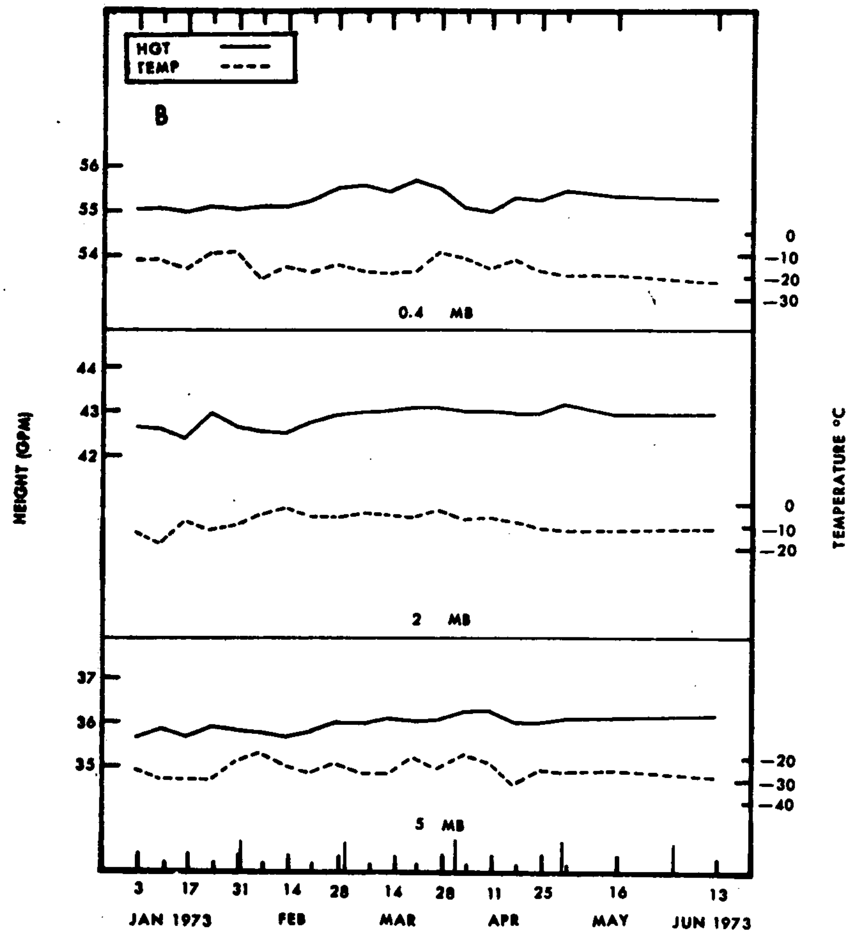


Figure 8b. Same as 8a for January to June 1973.

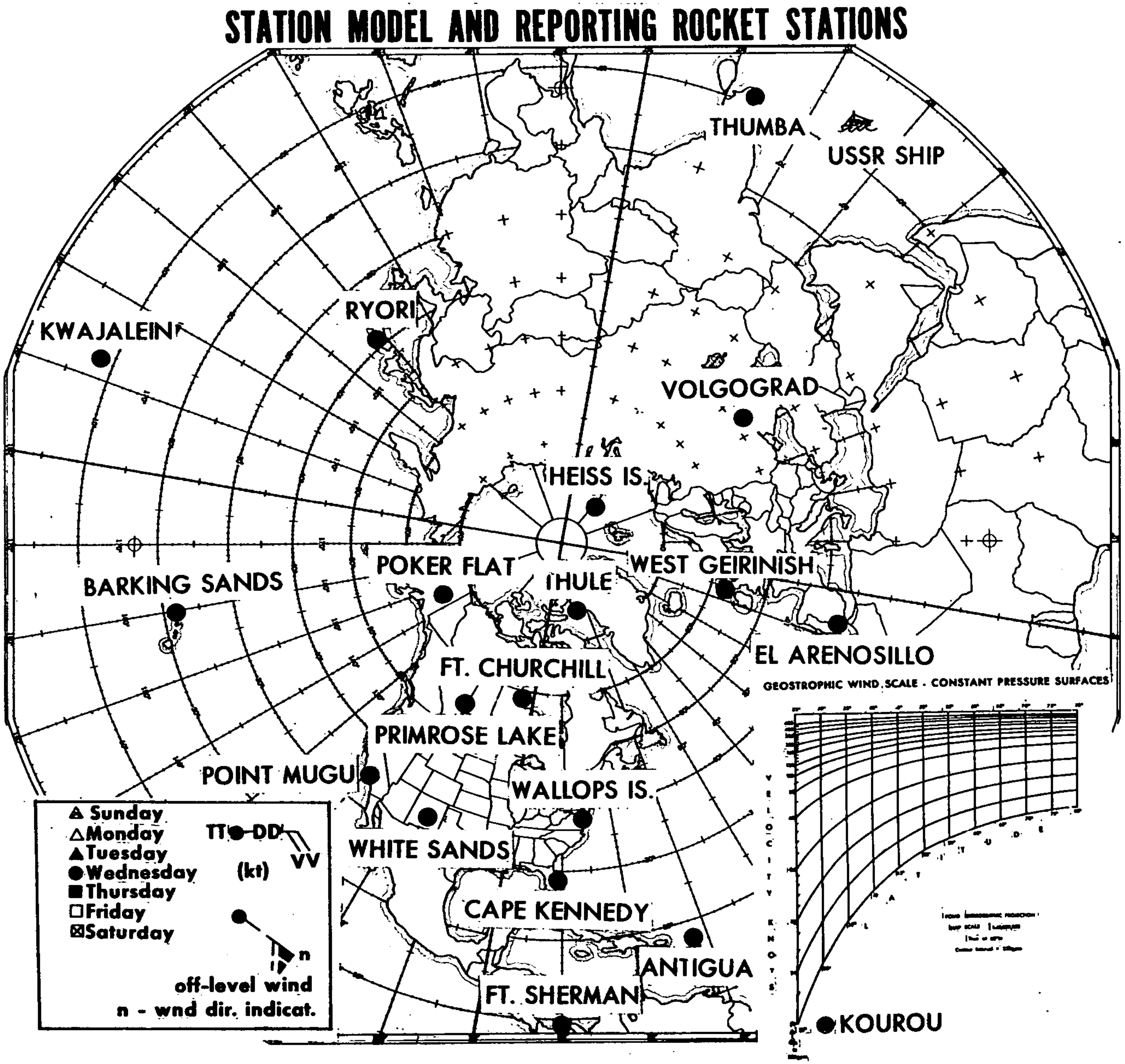
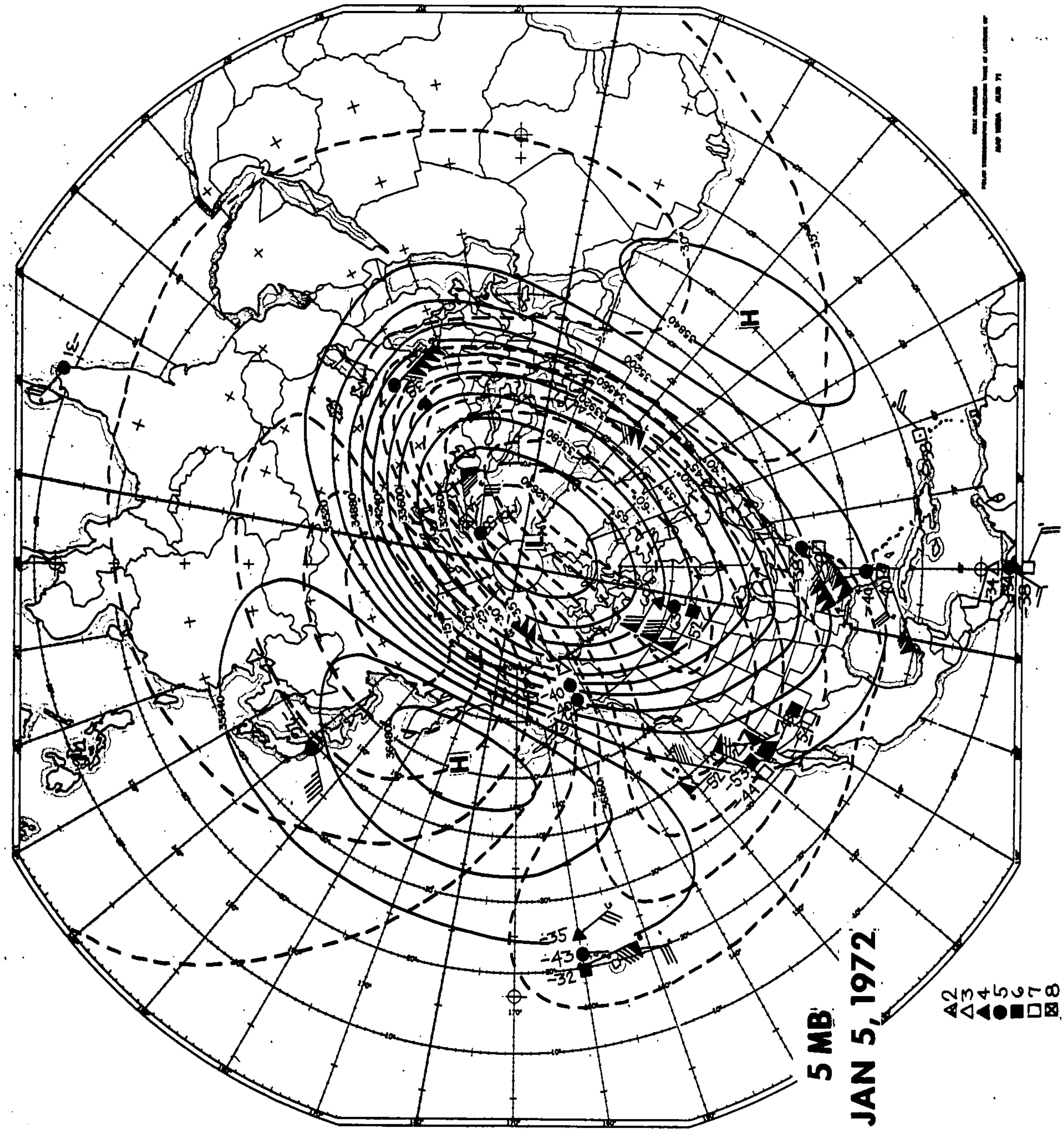


Figure 9. Station ... and the re... rocket stations.



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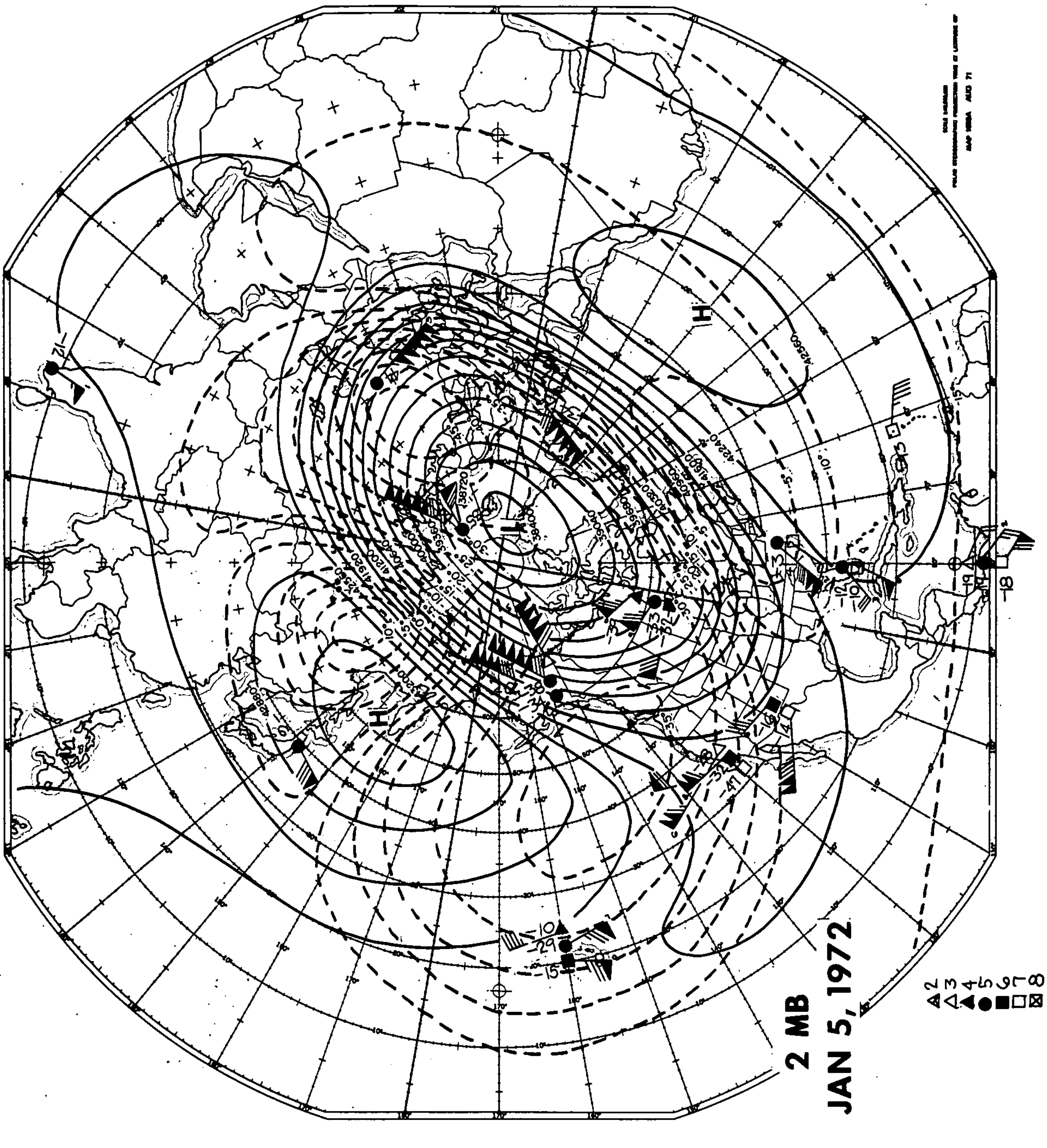
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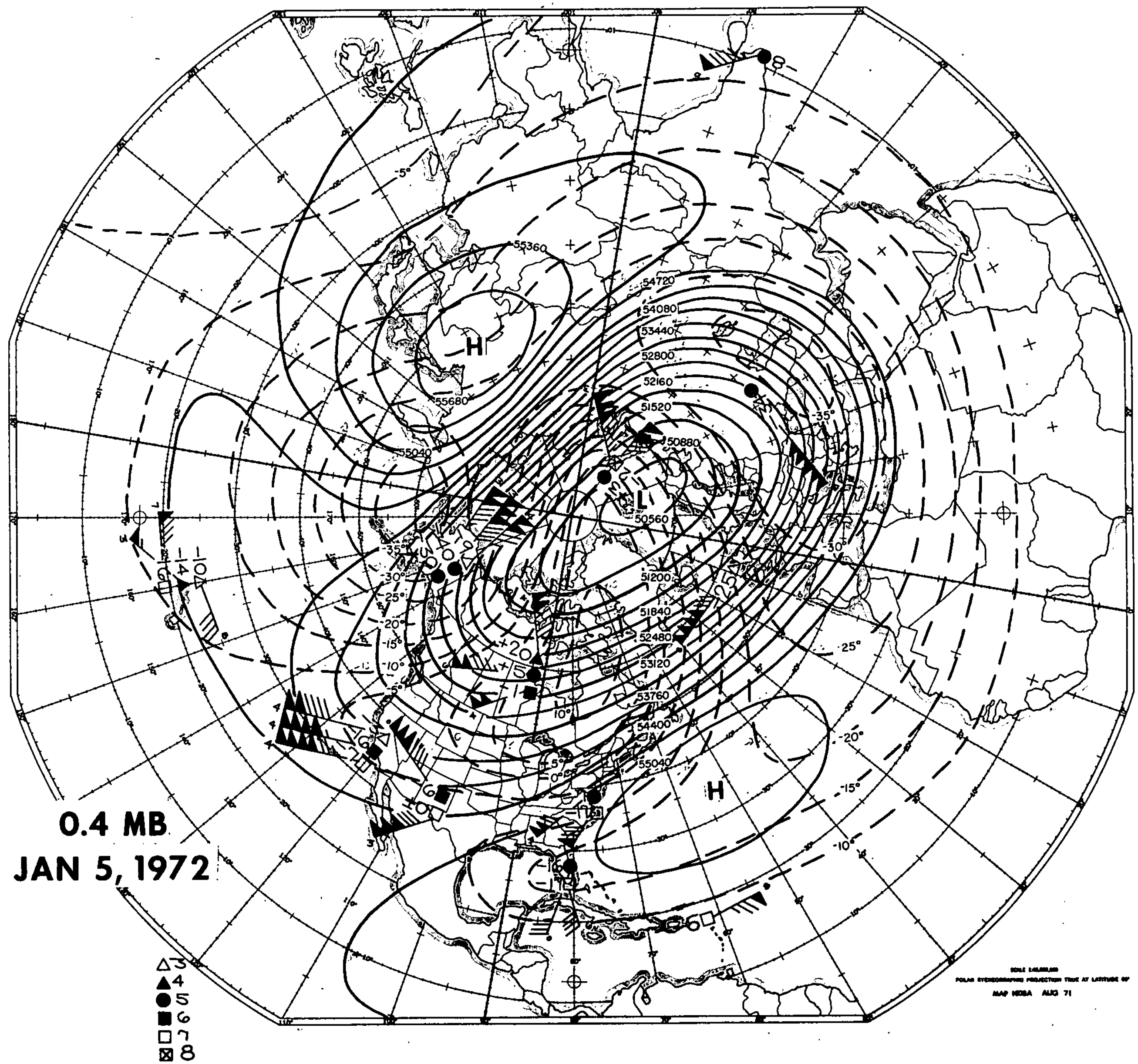
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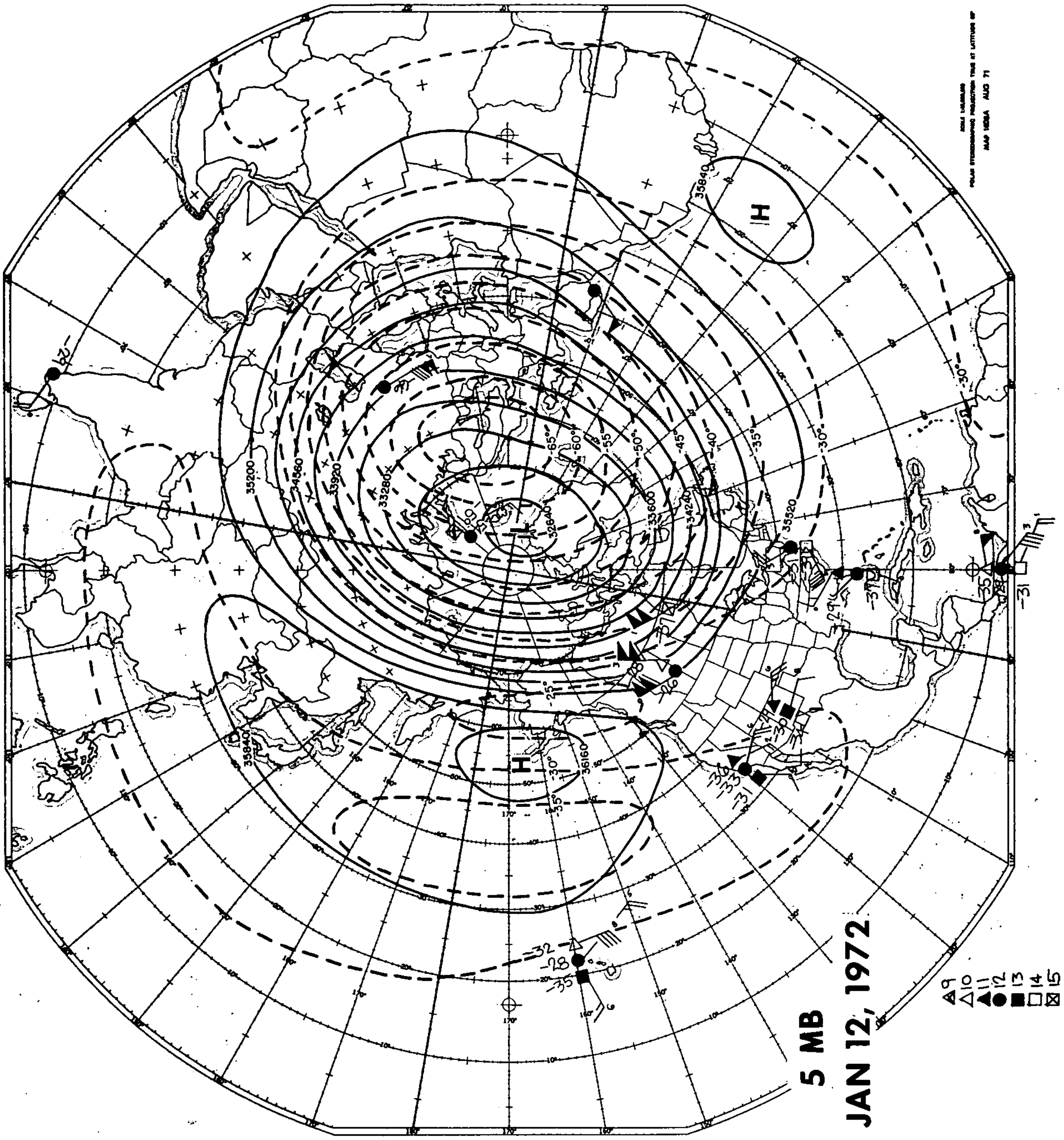

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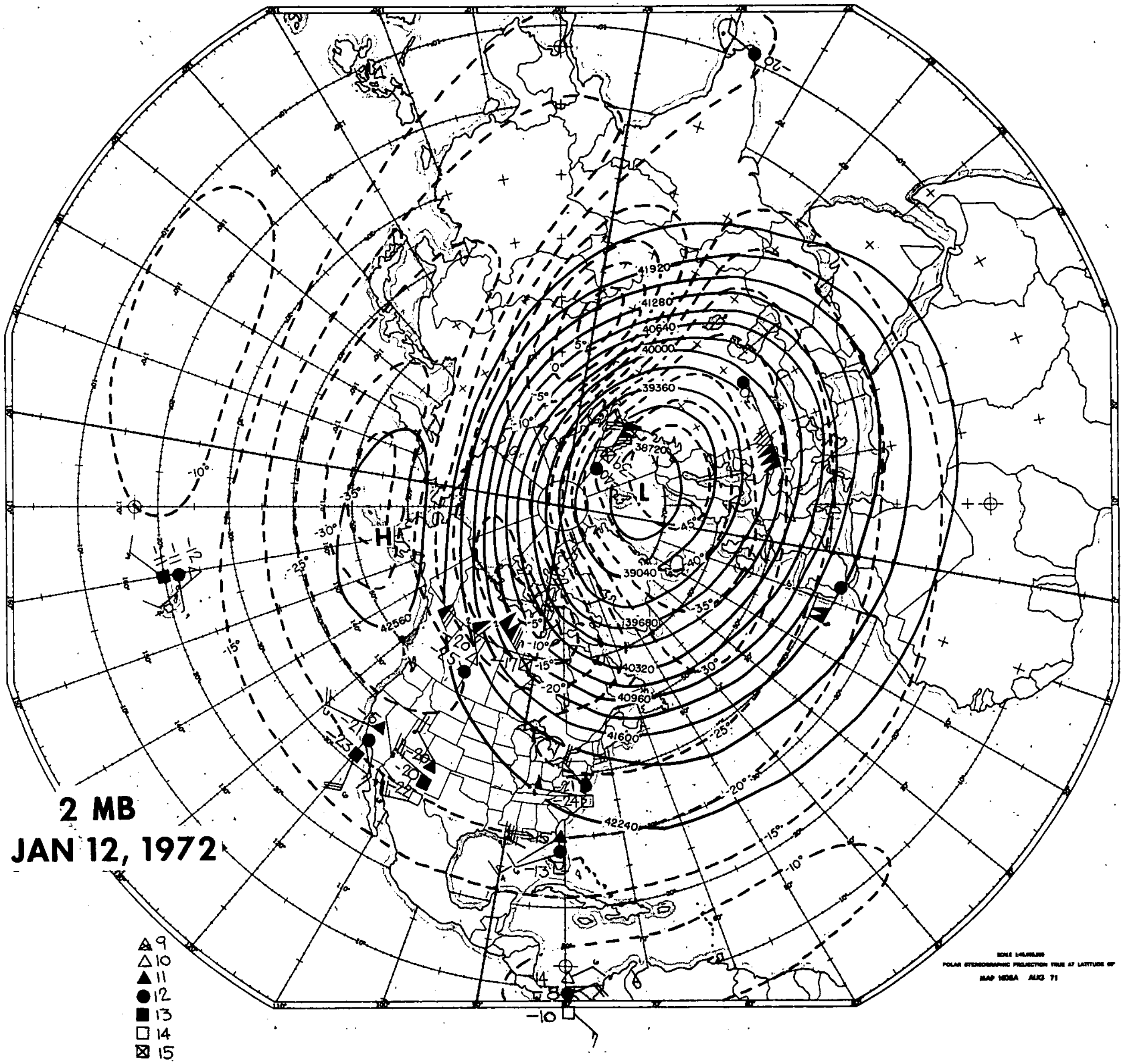

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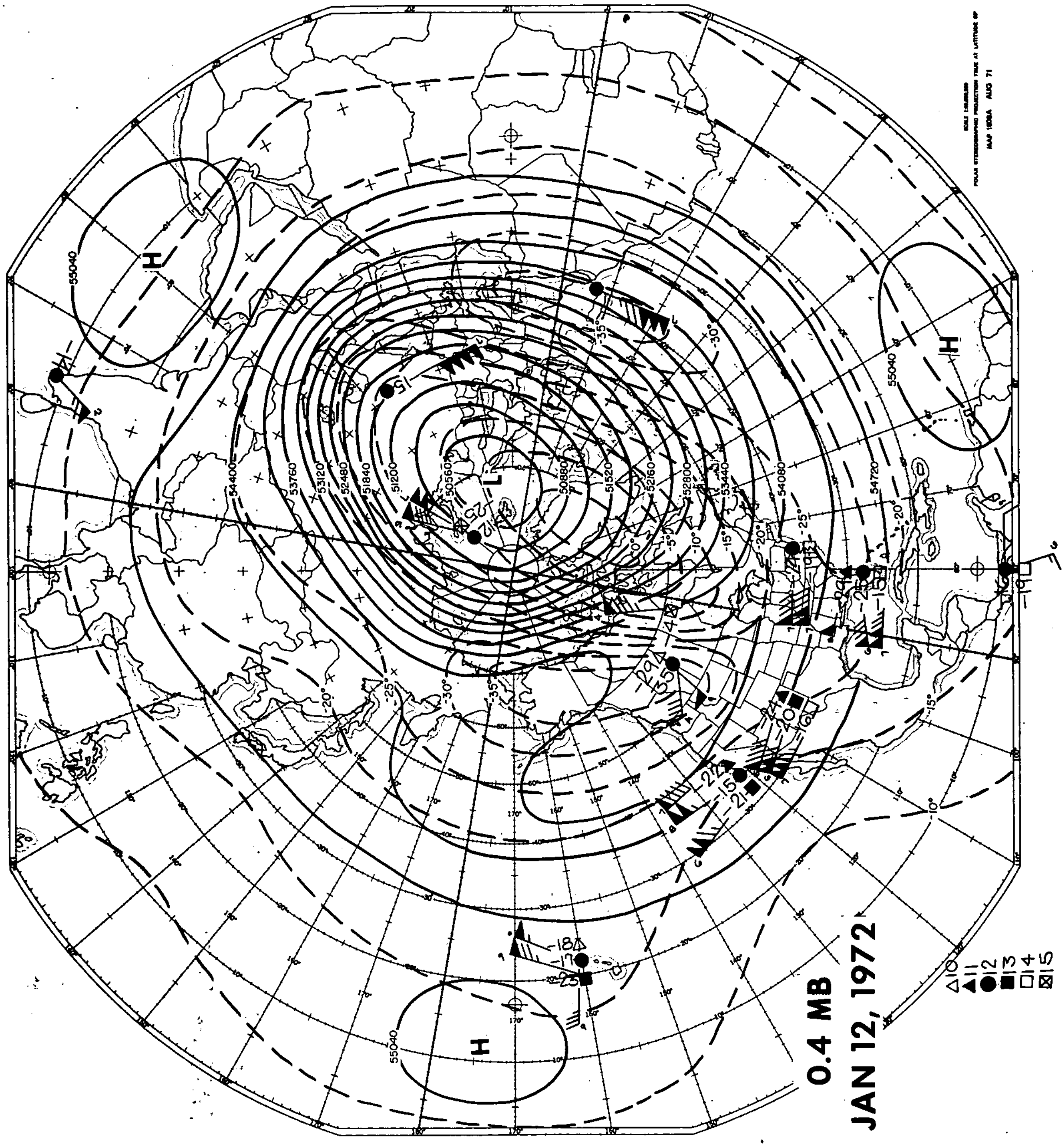

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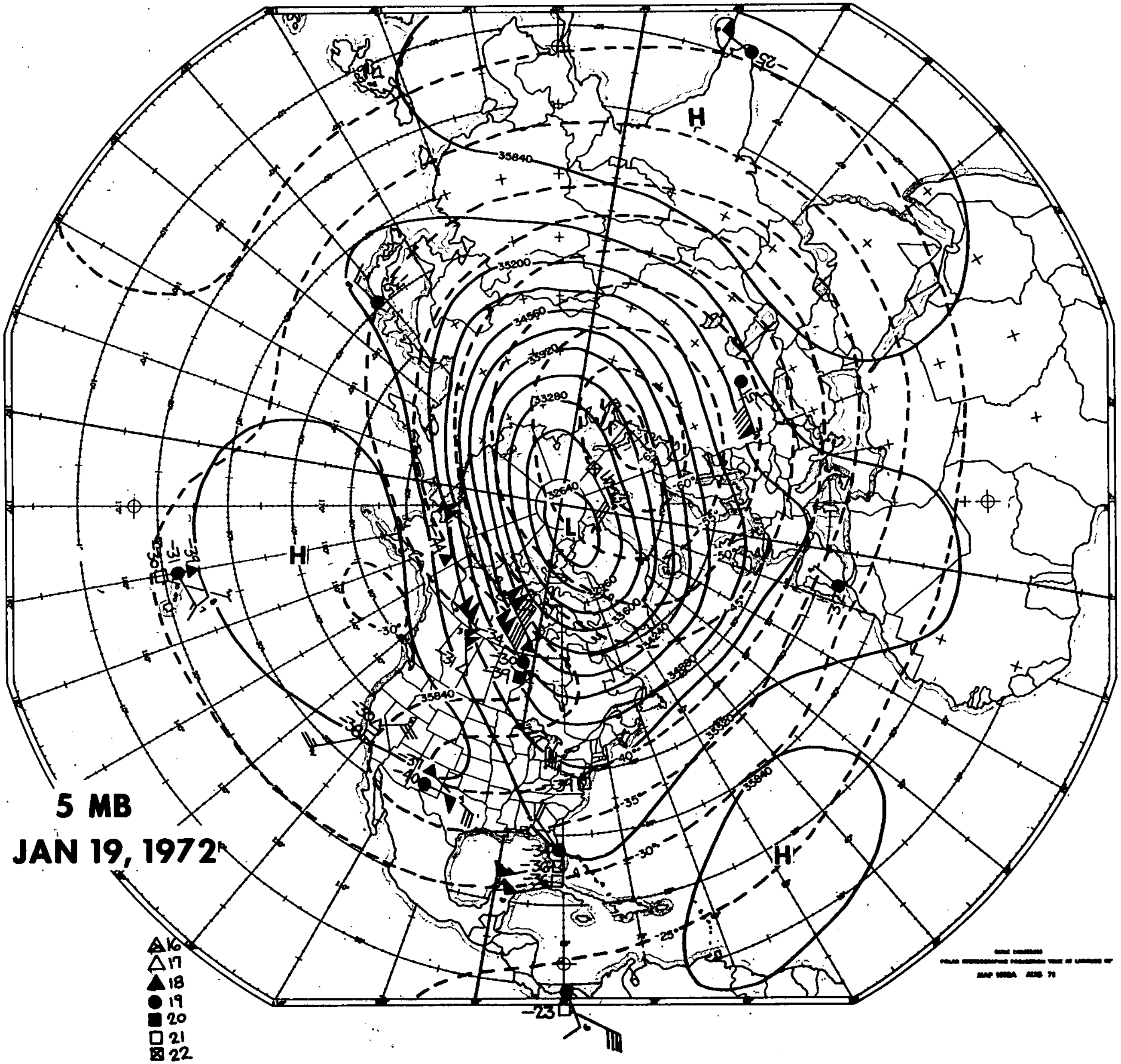

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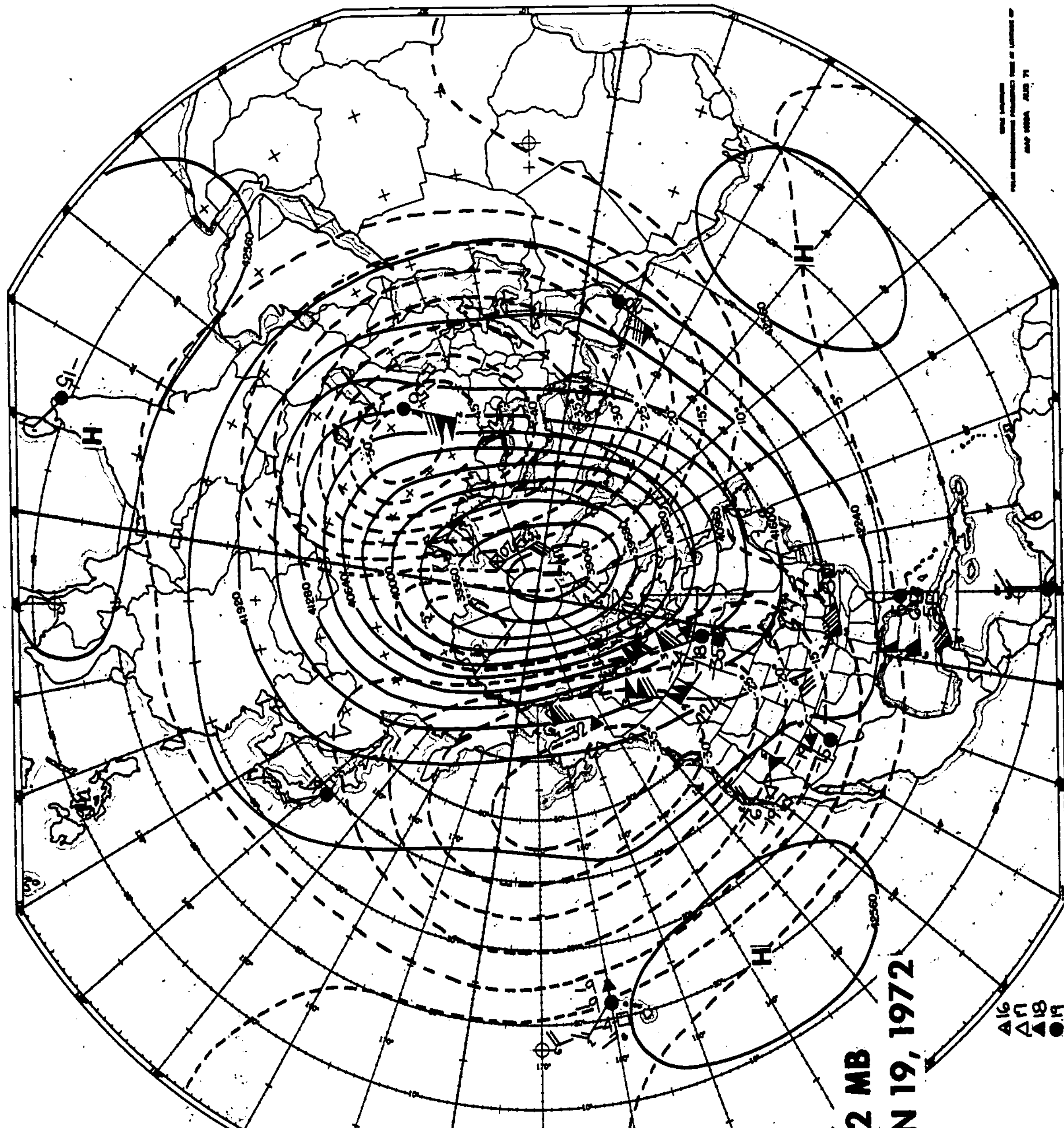
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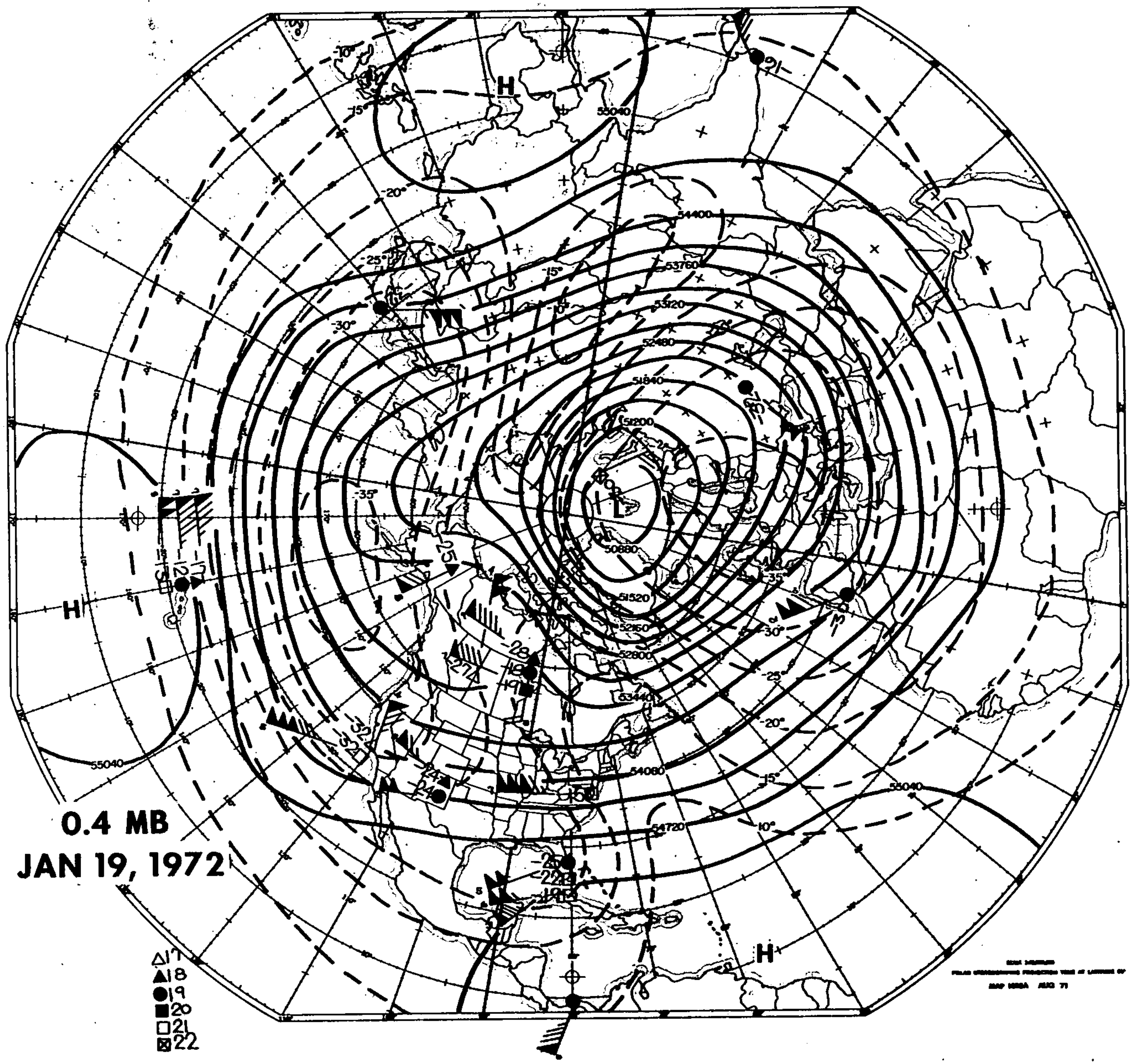

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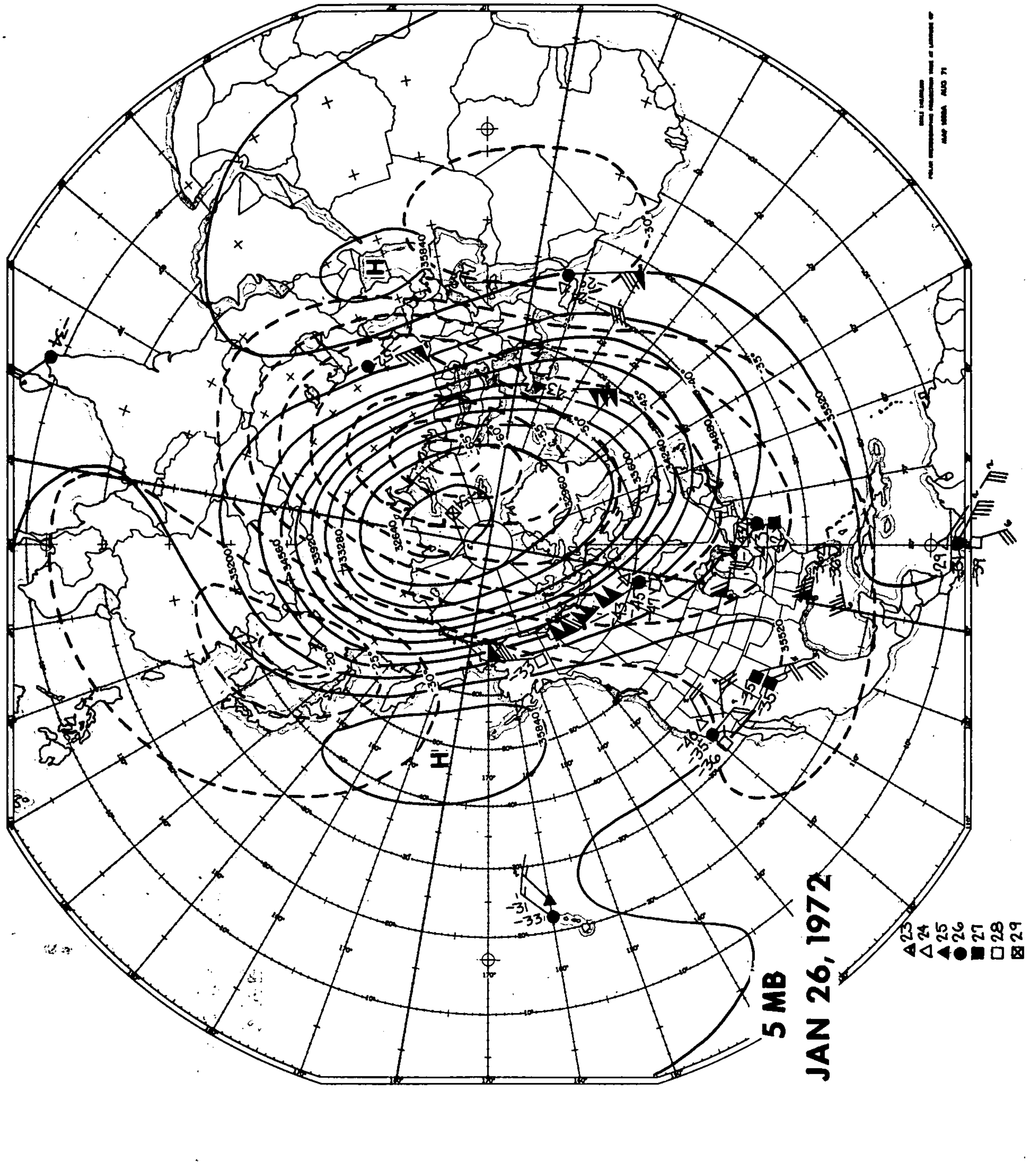
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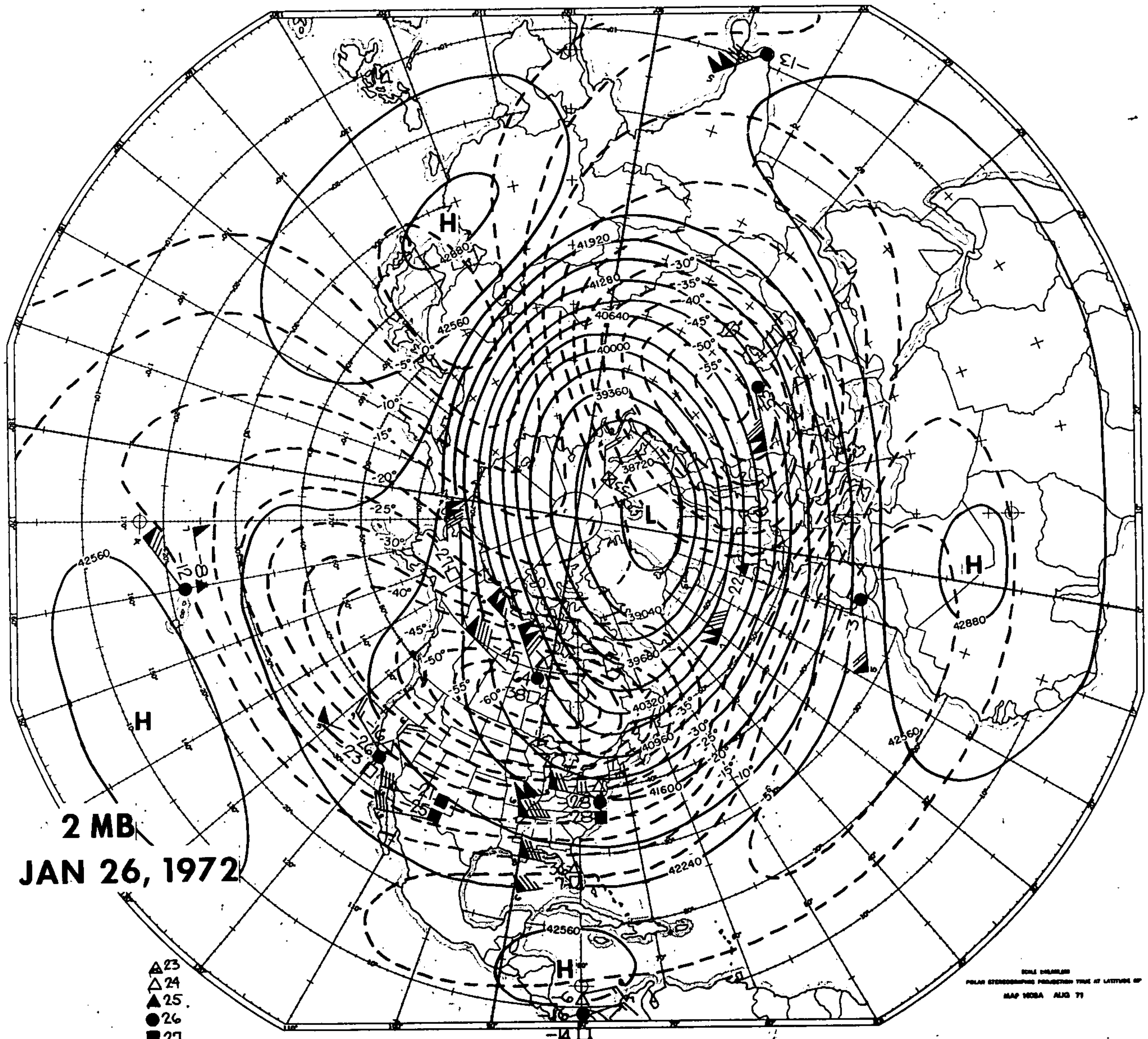

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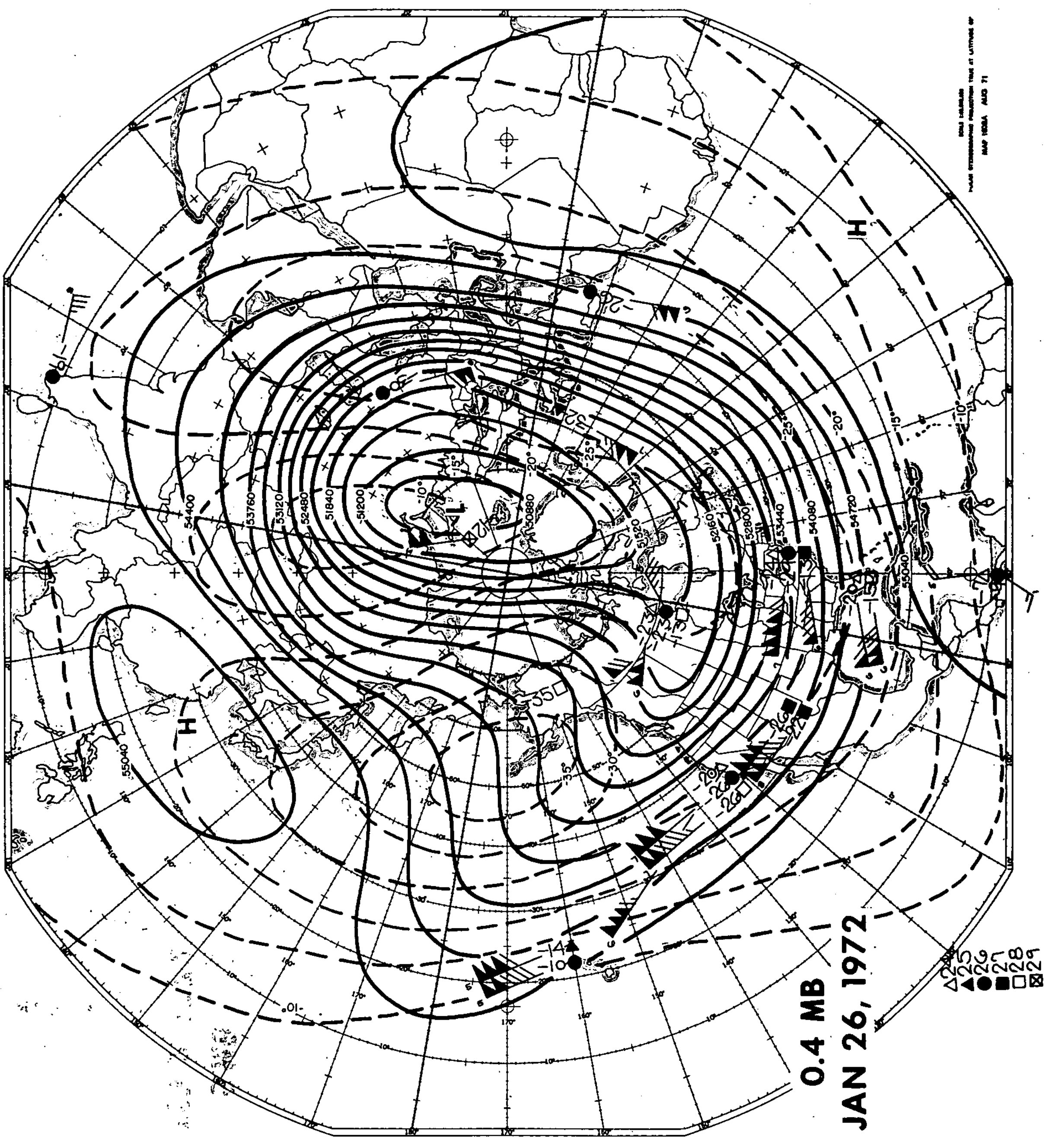

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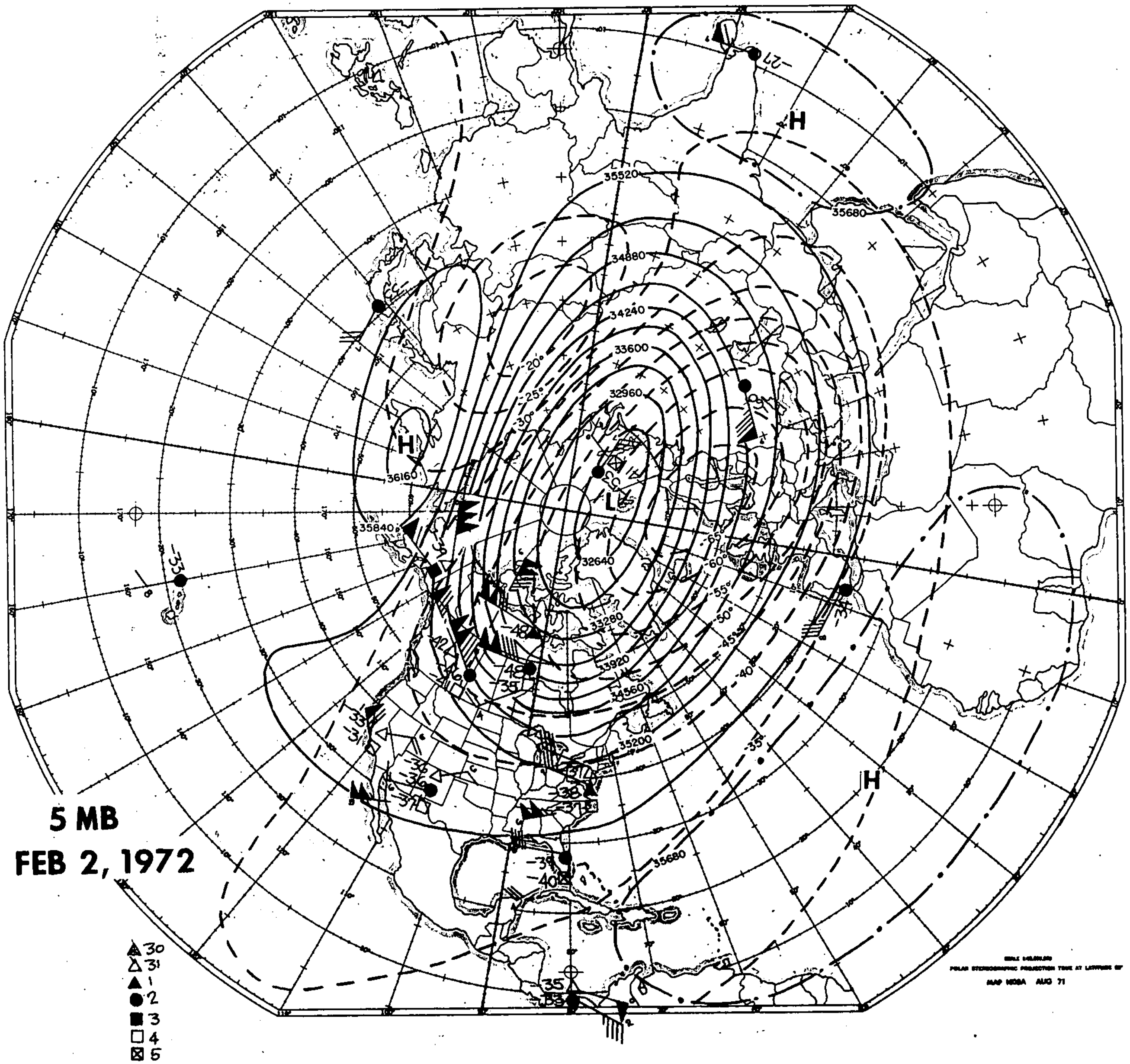

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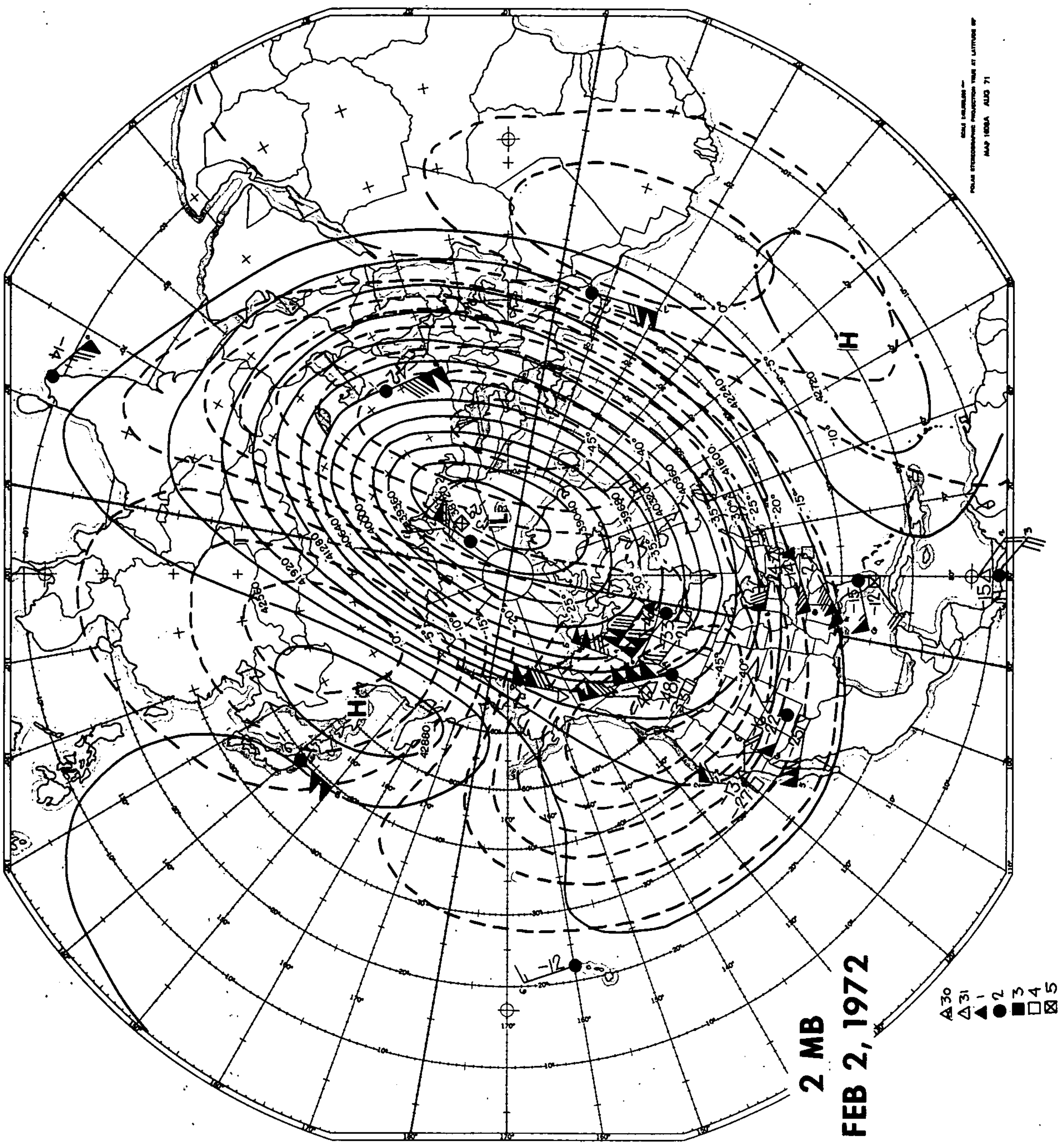
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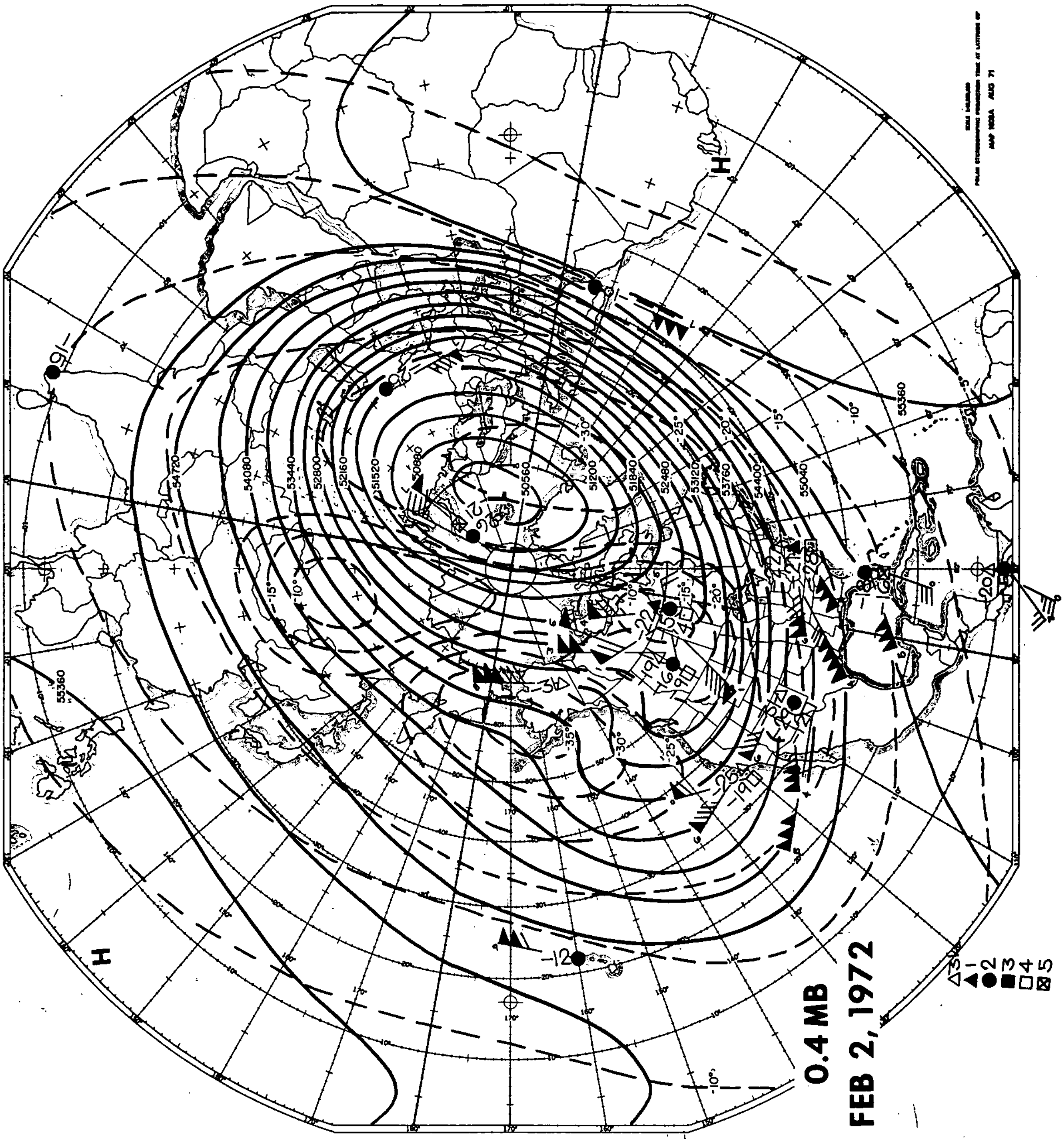

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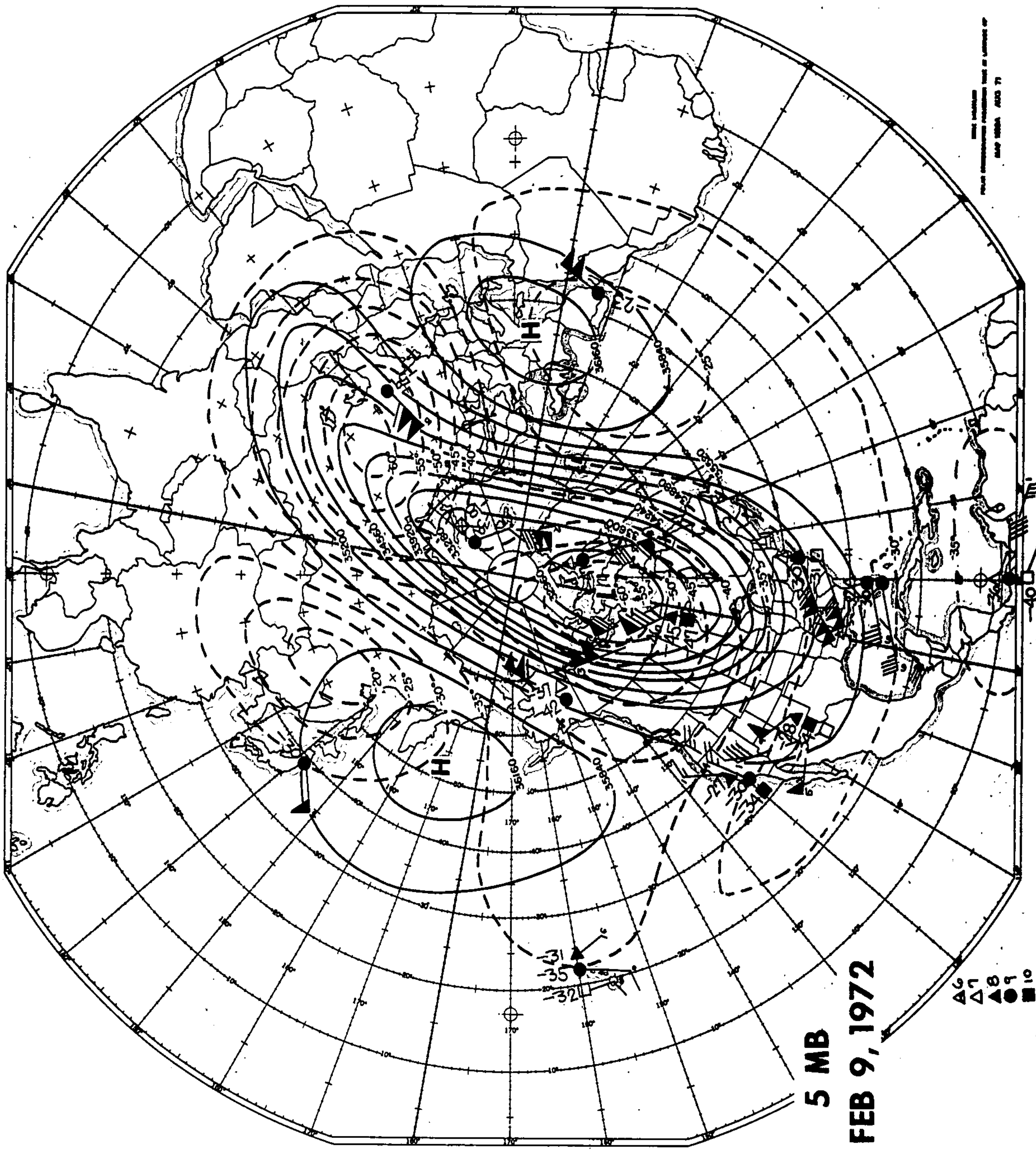

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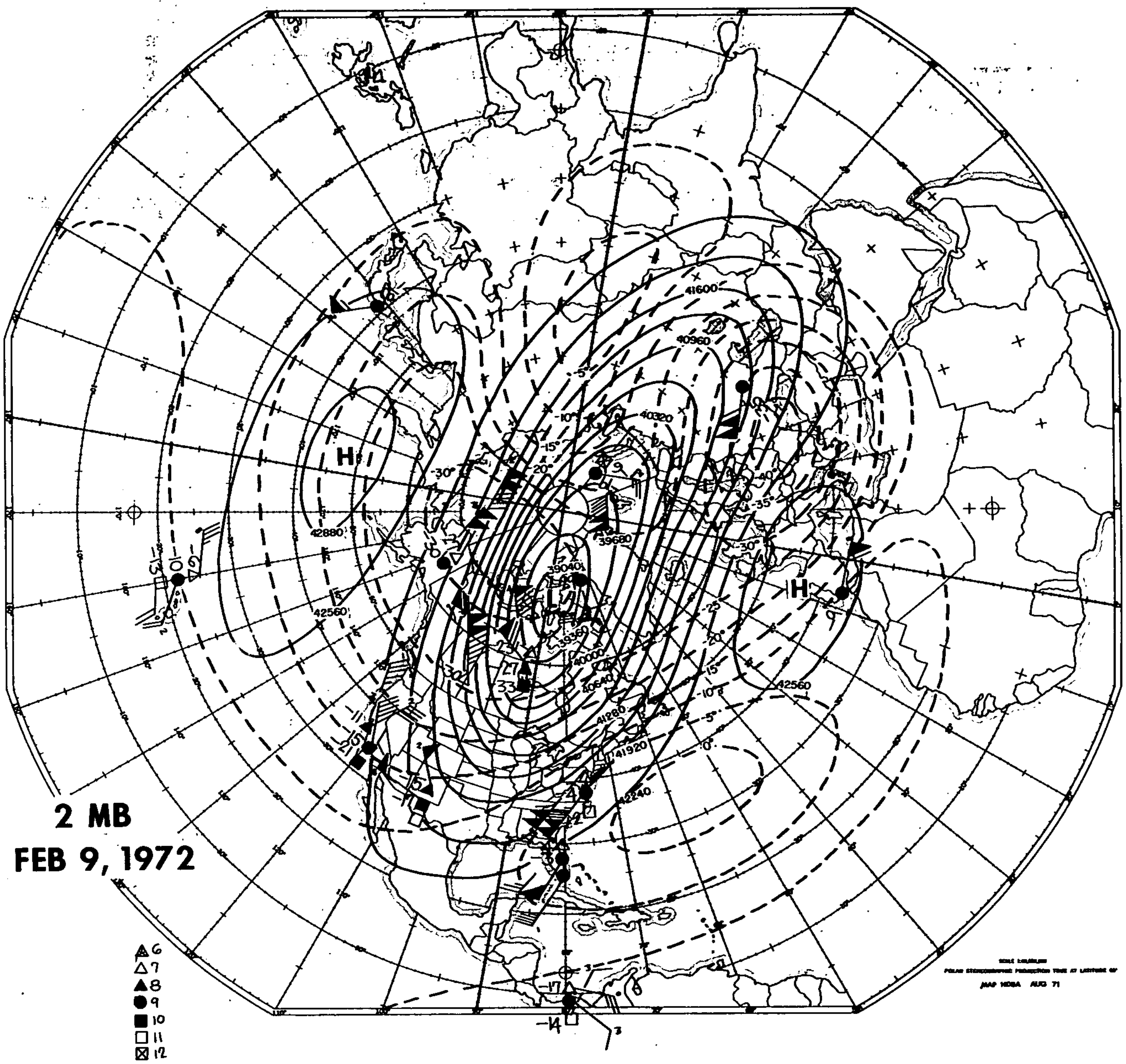

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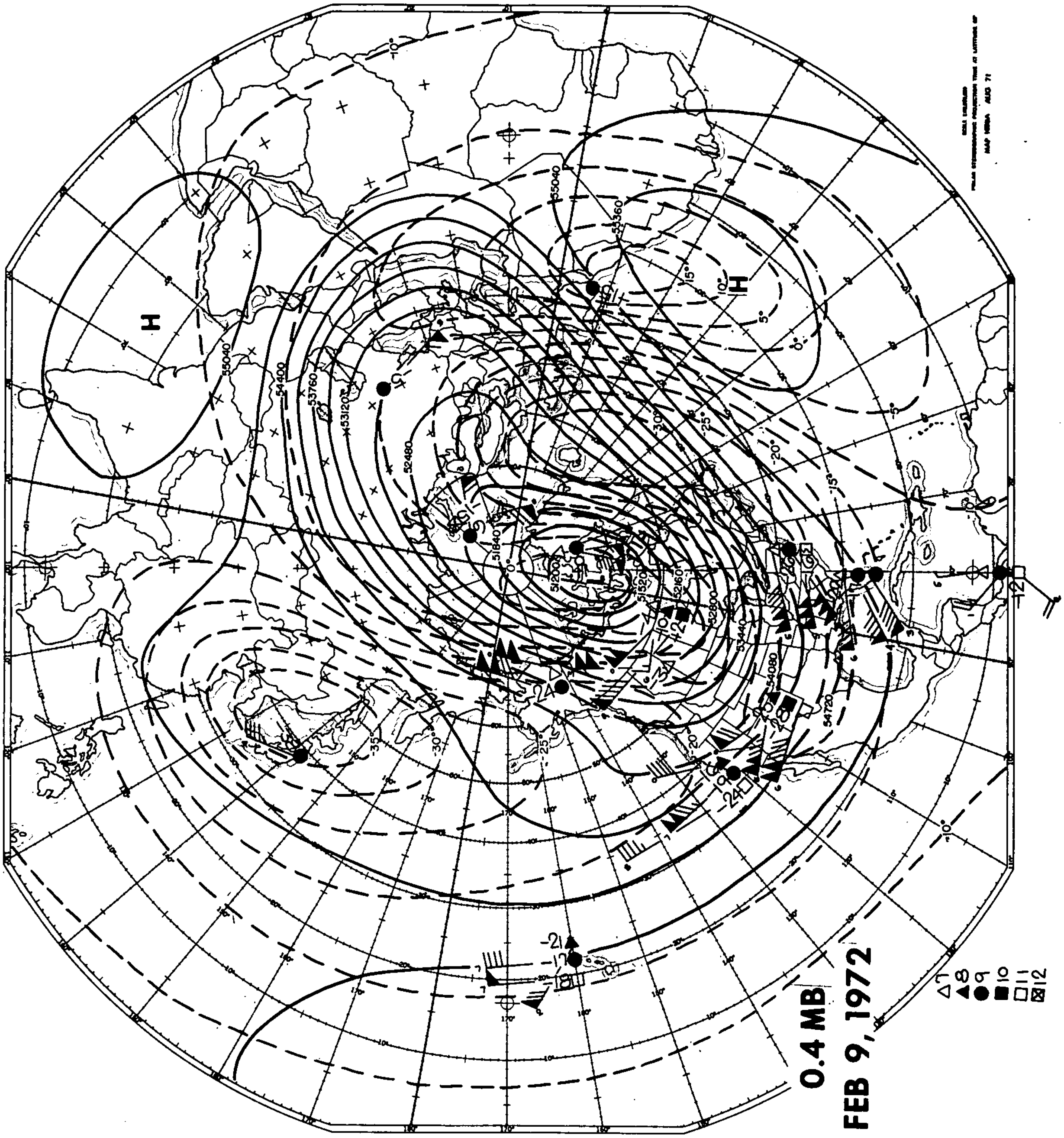
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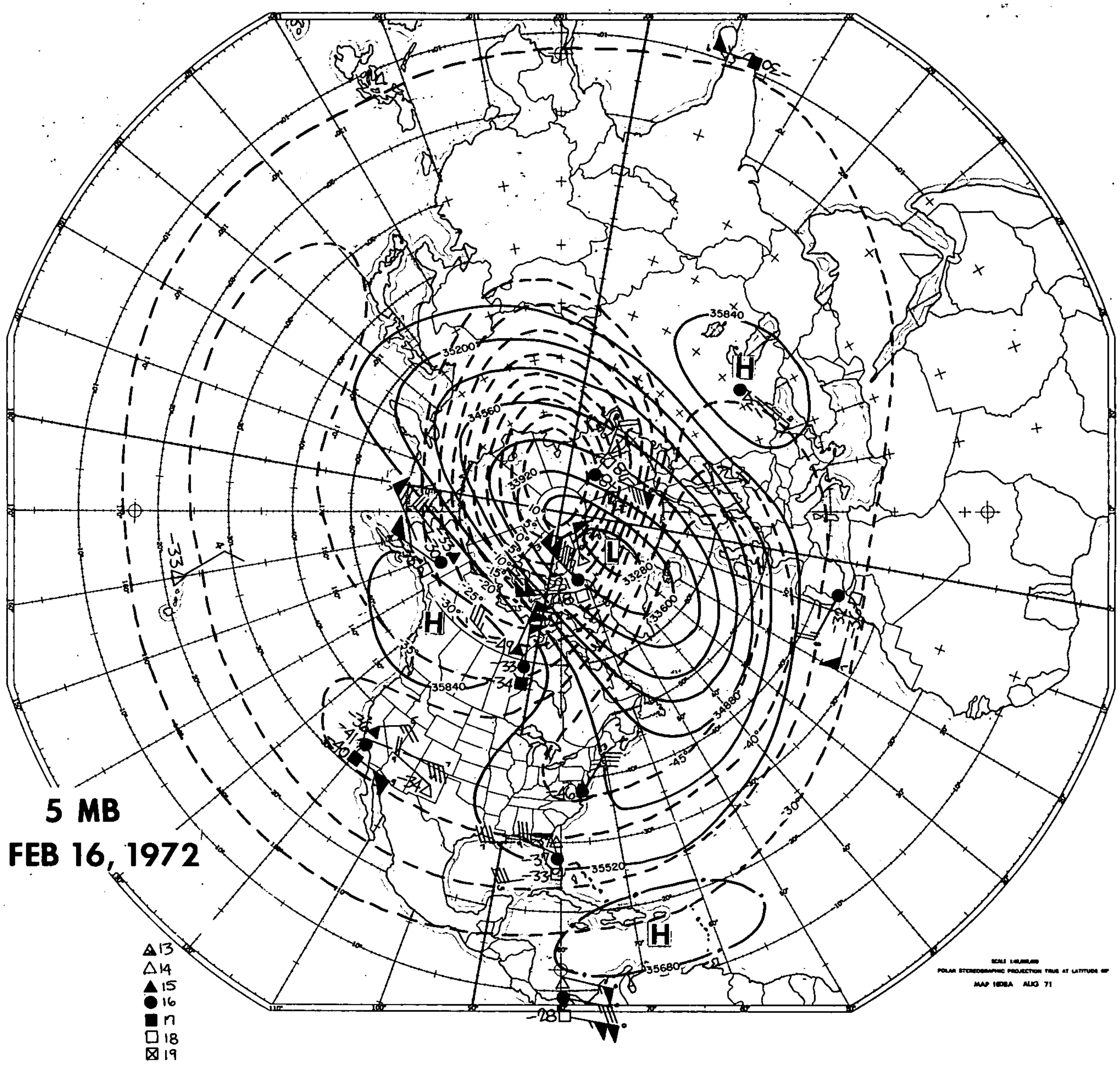
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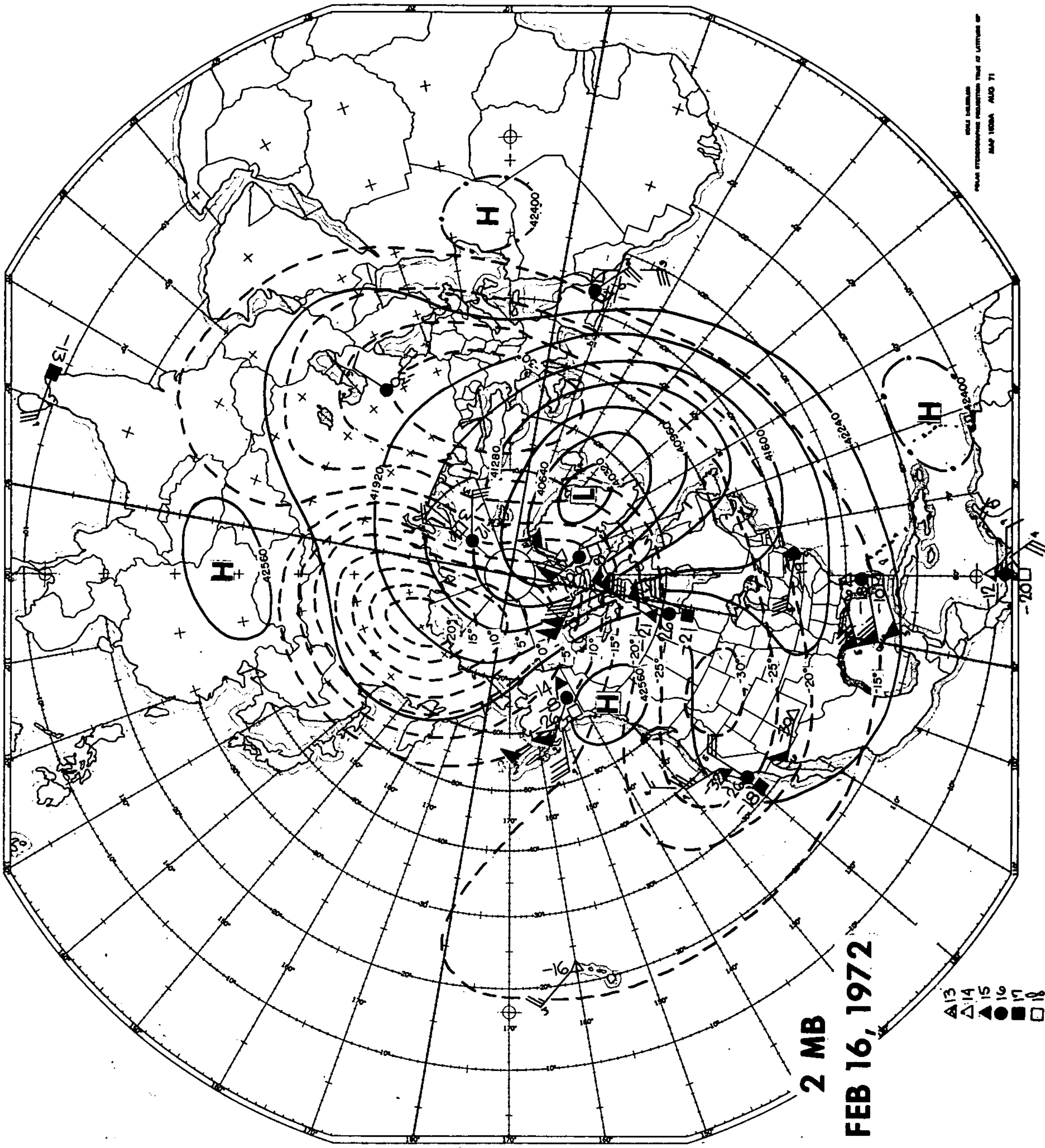

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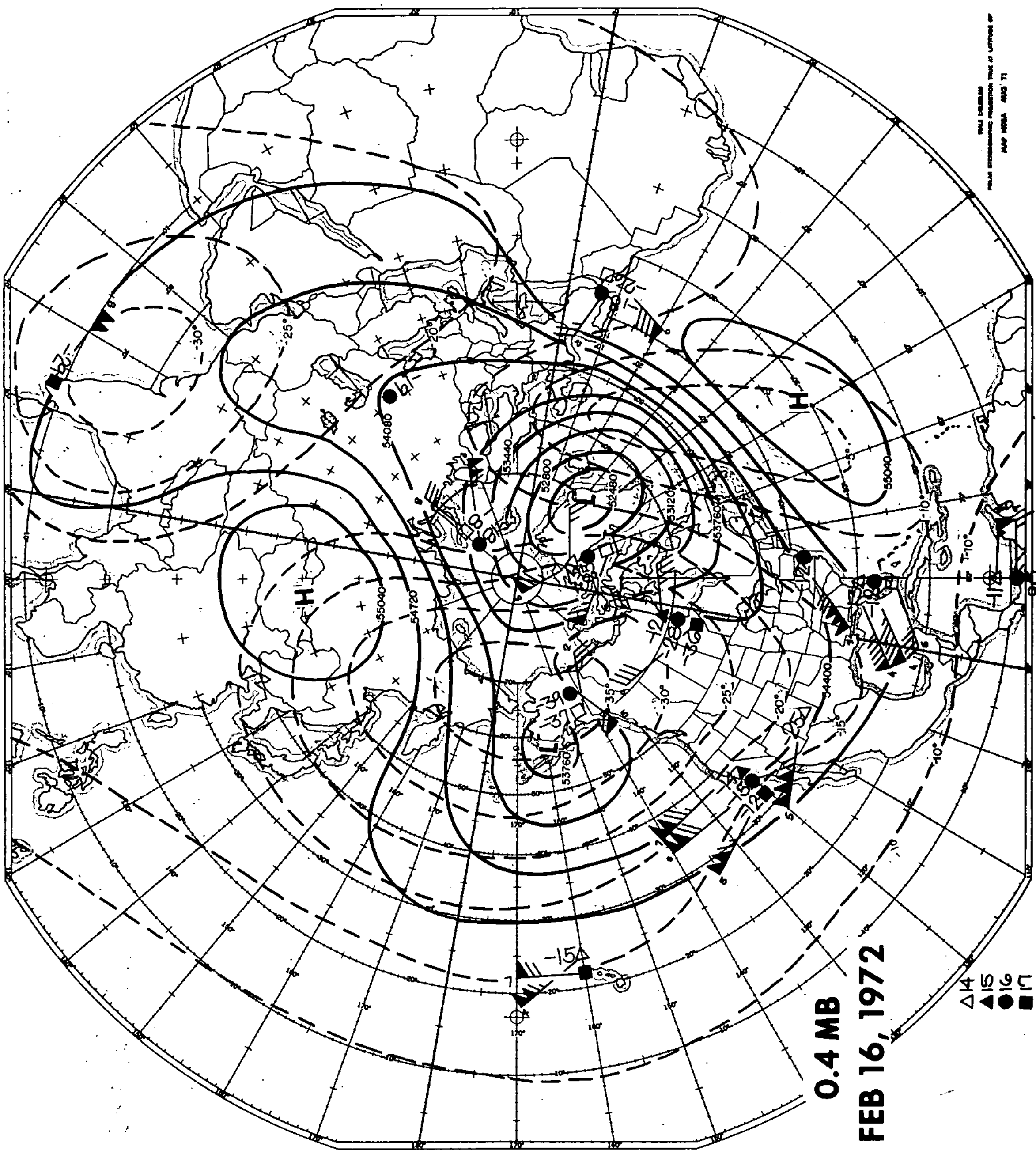

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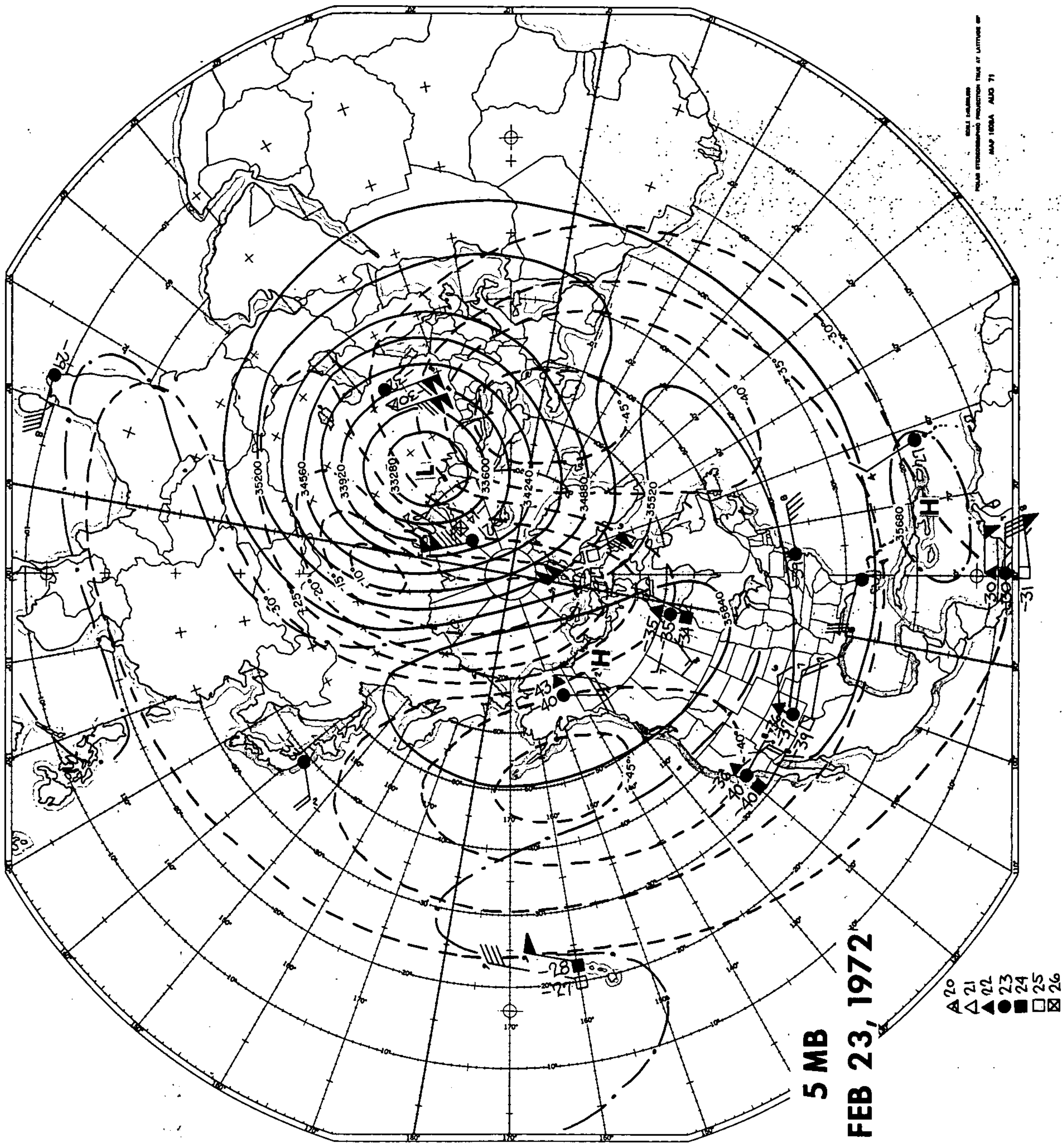
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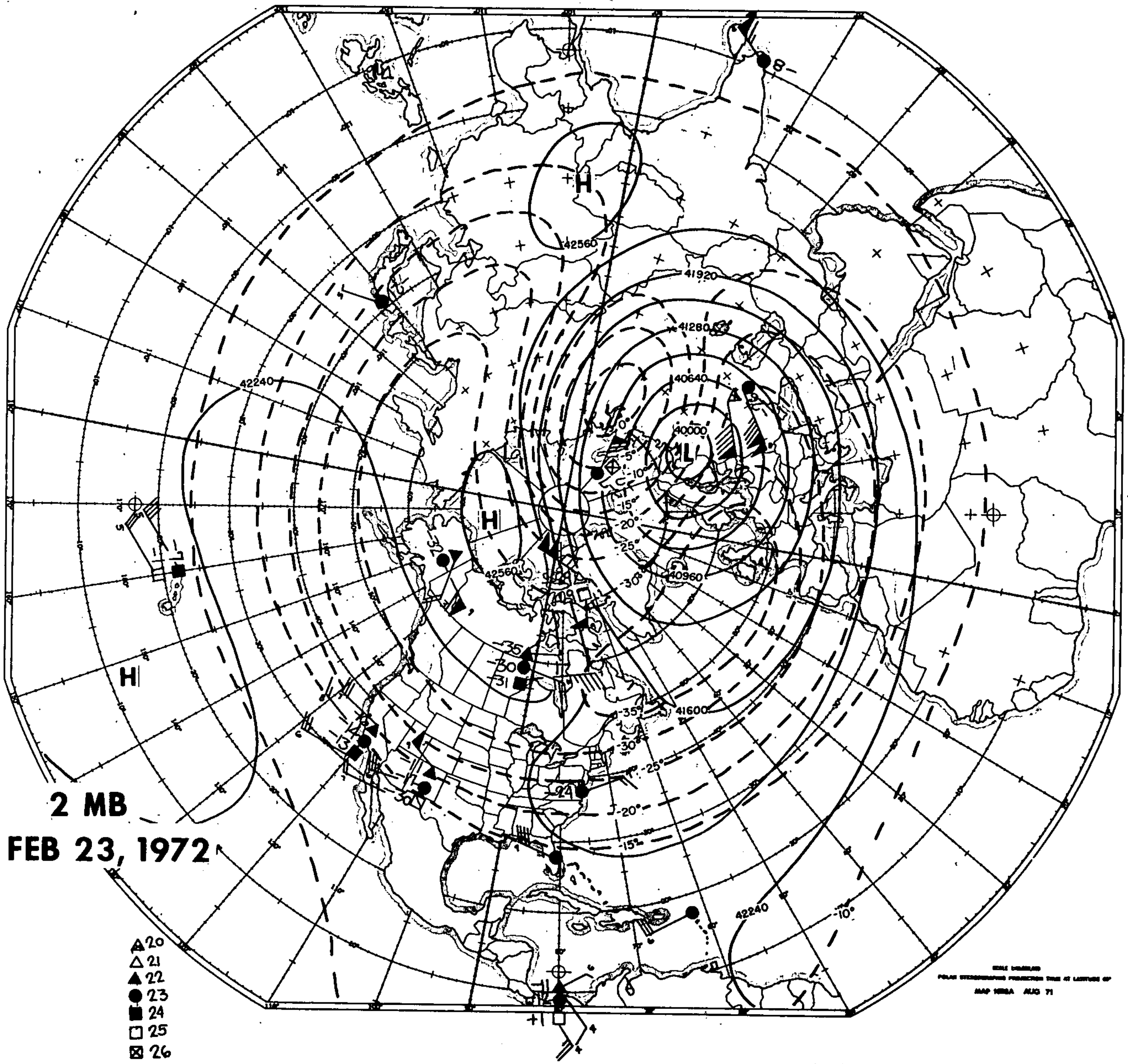

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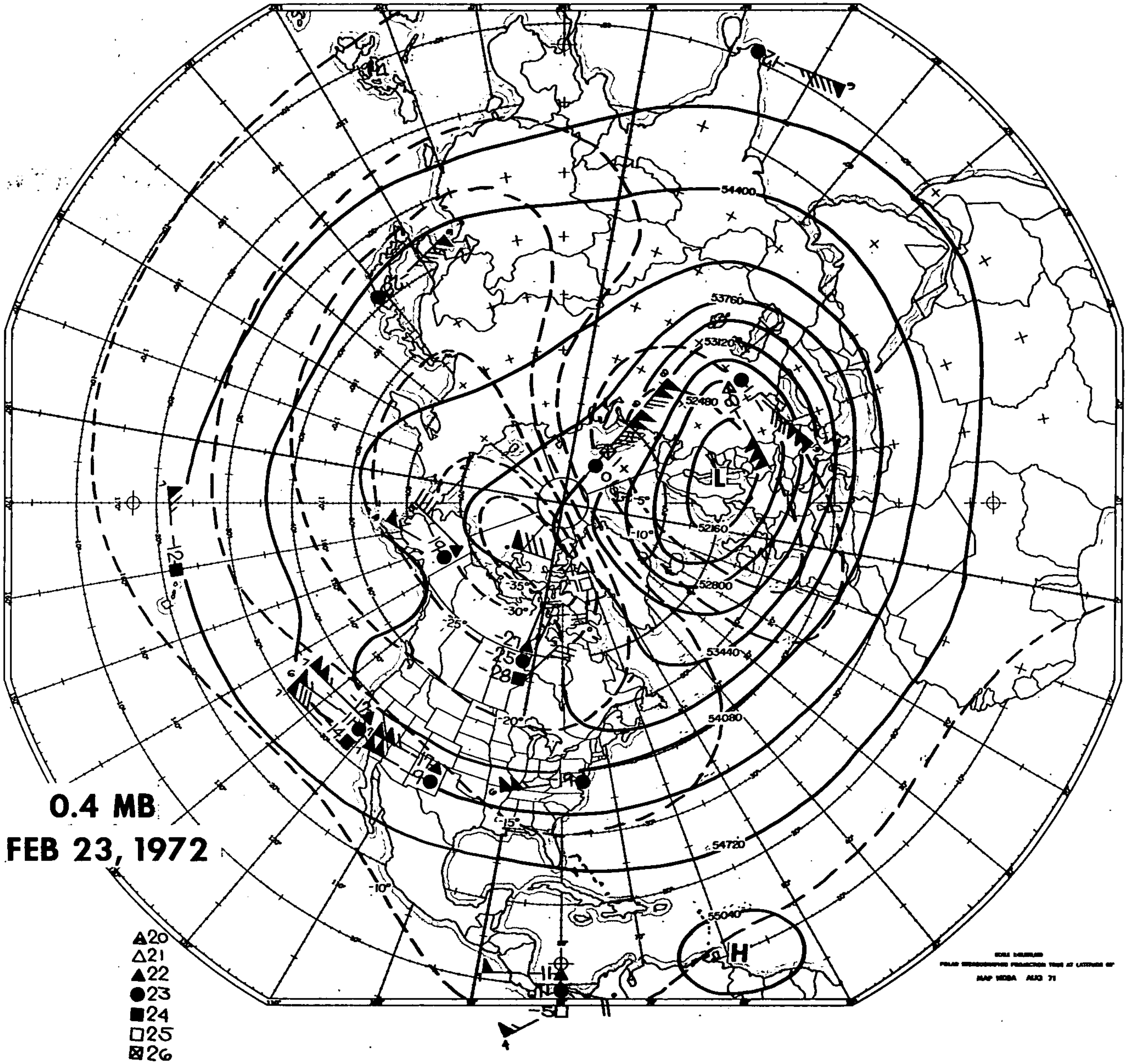

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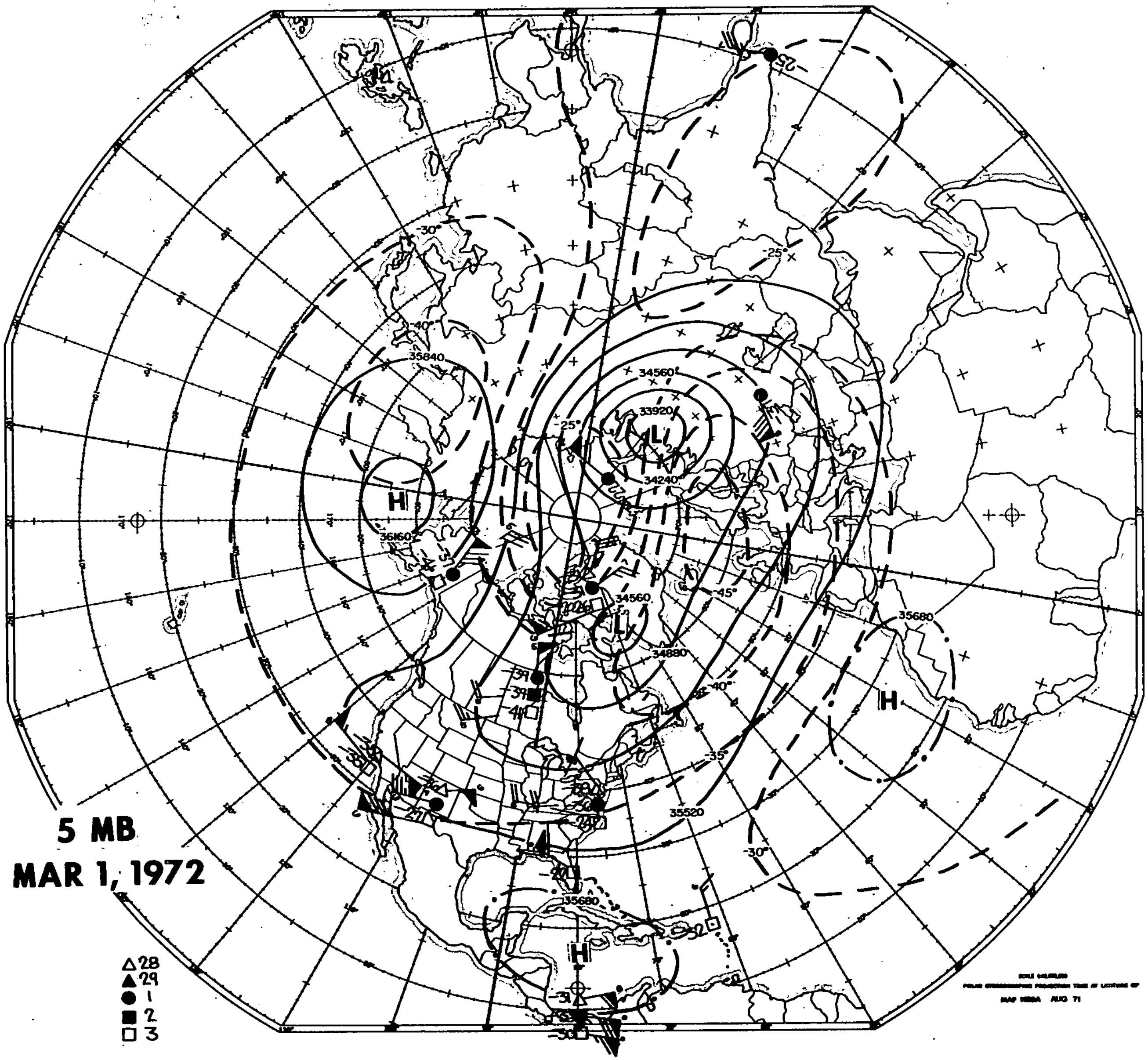

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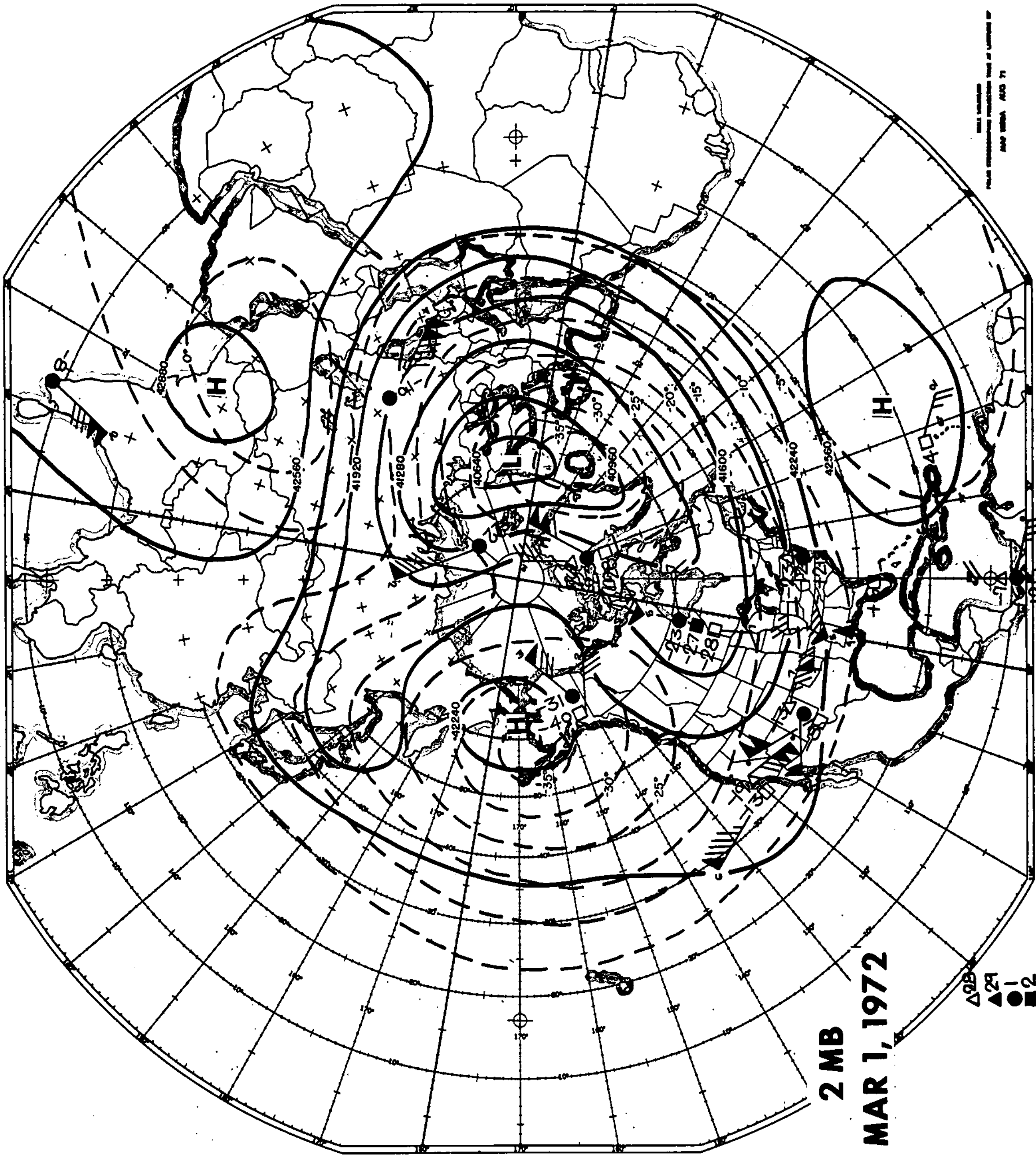

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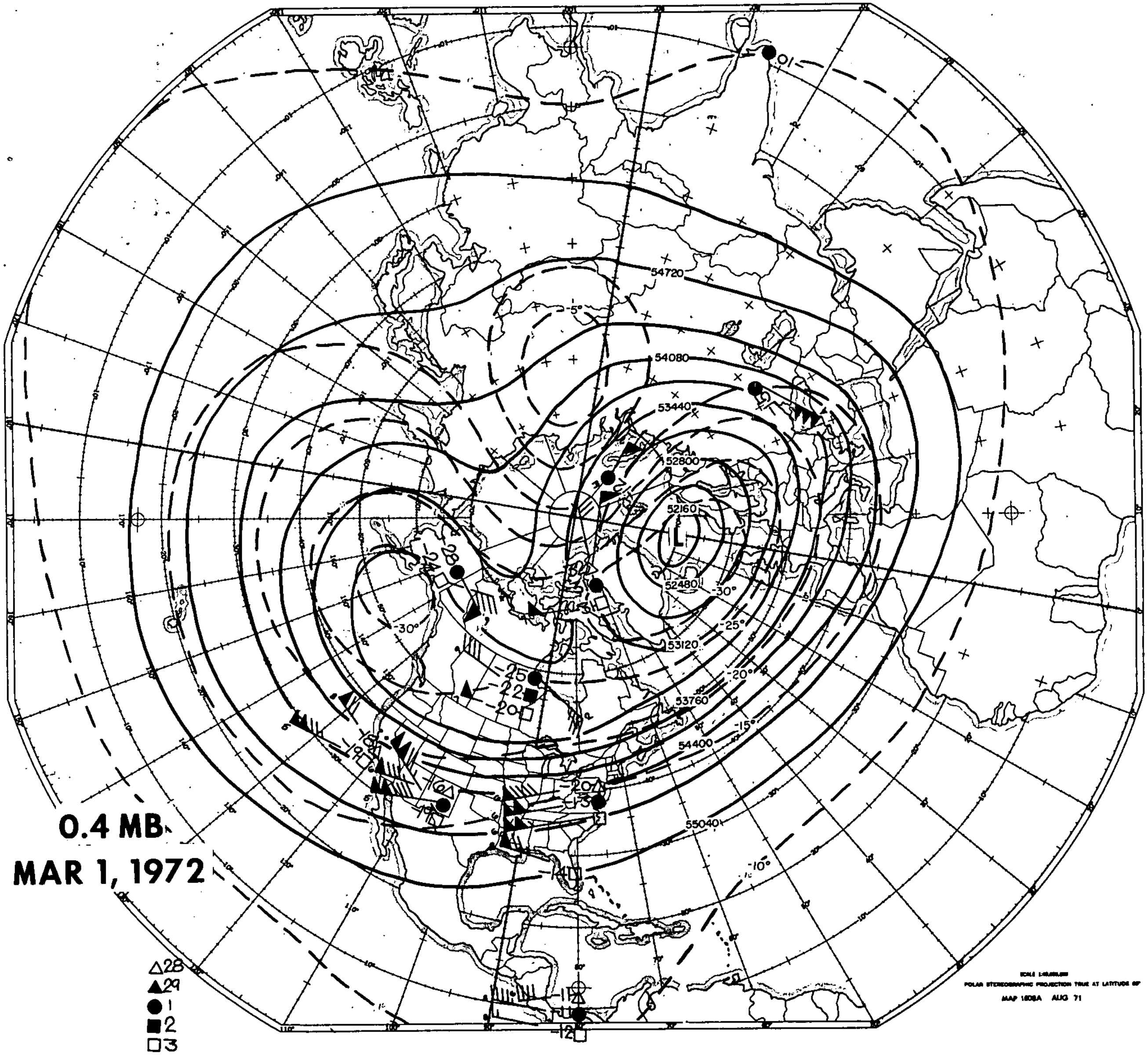

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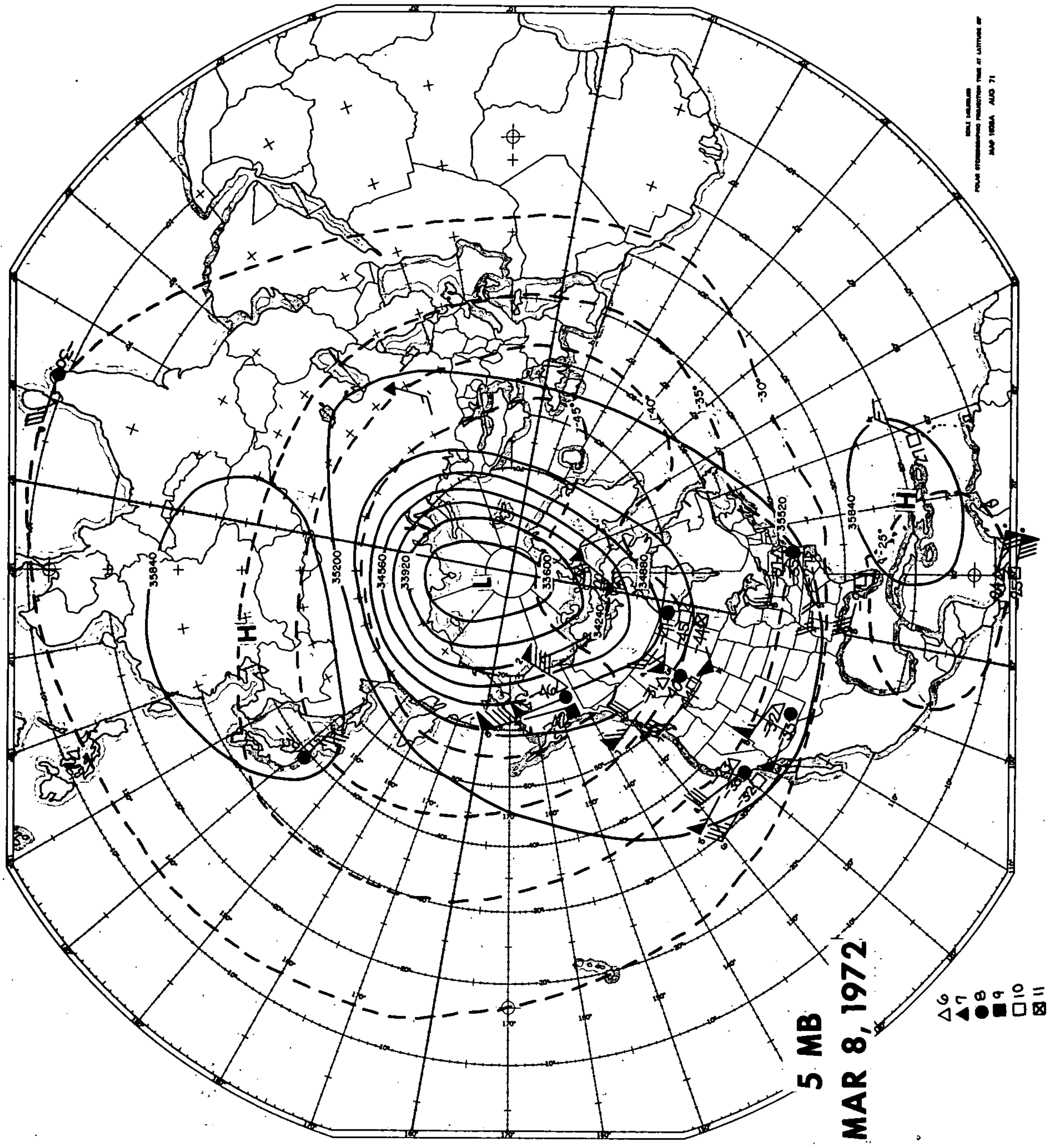

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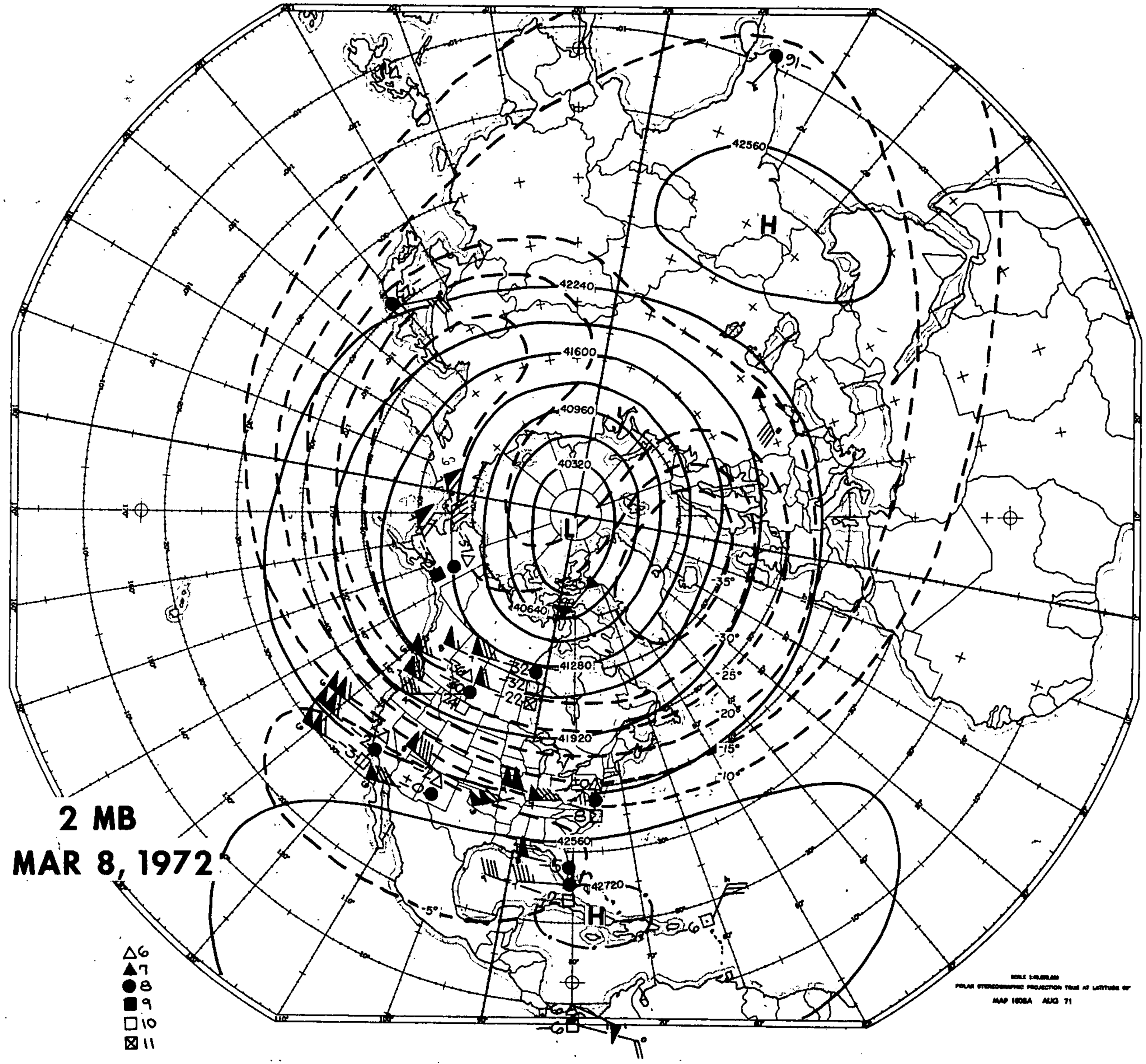

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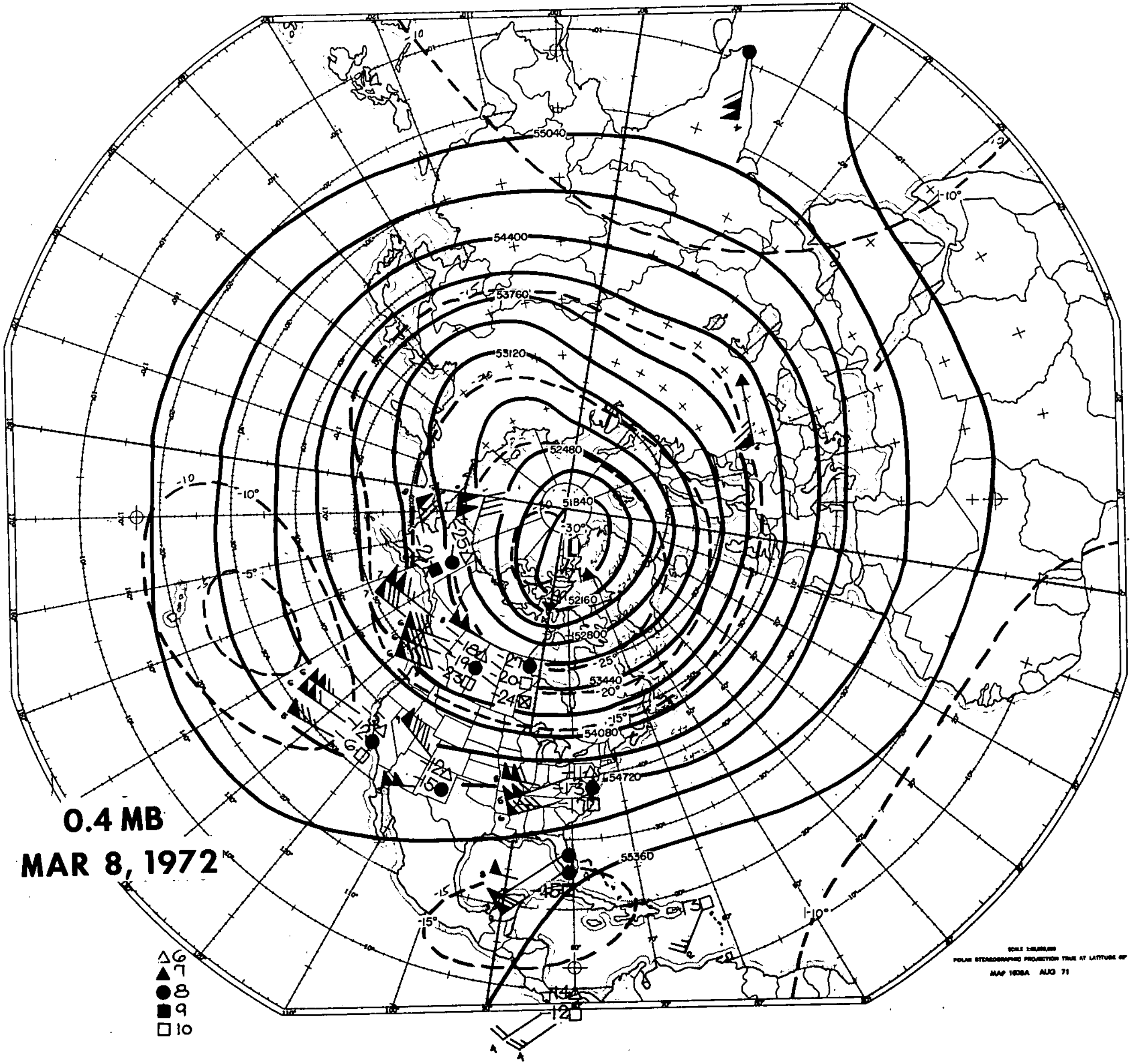

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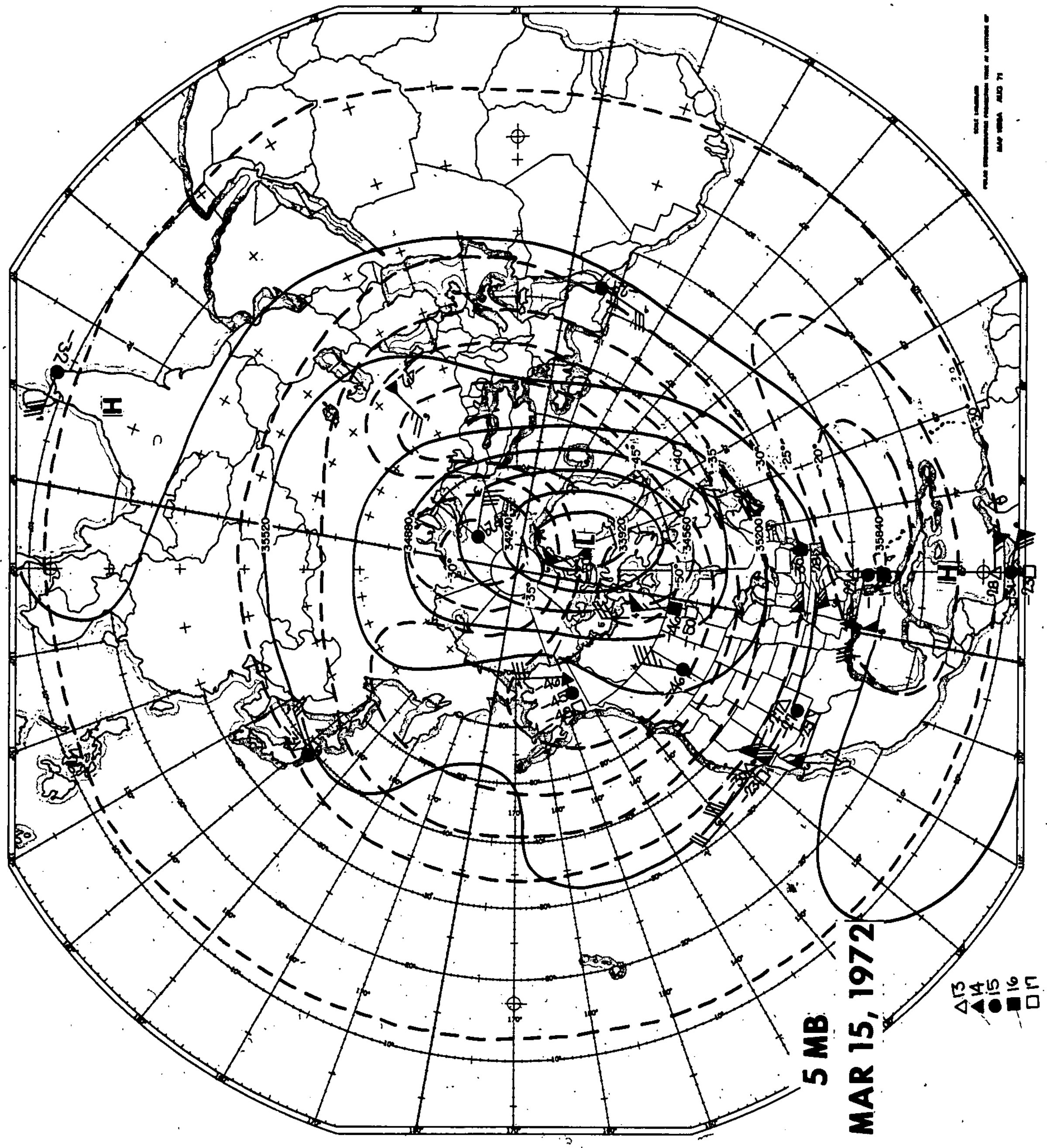
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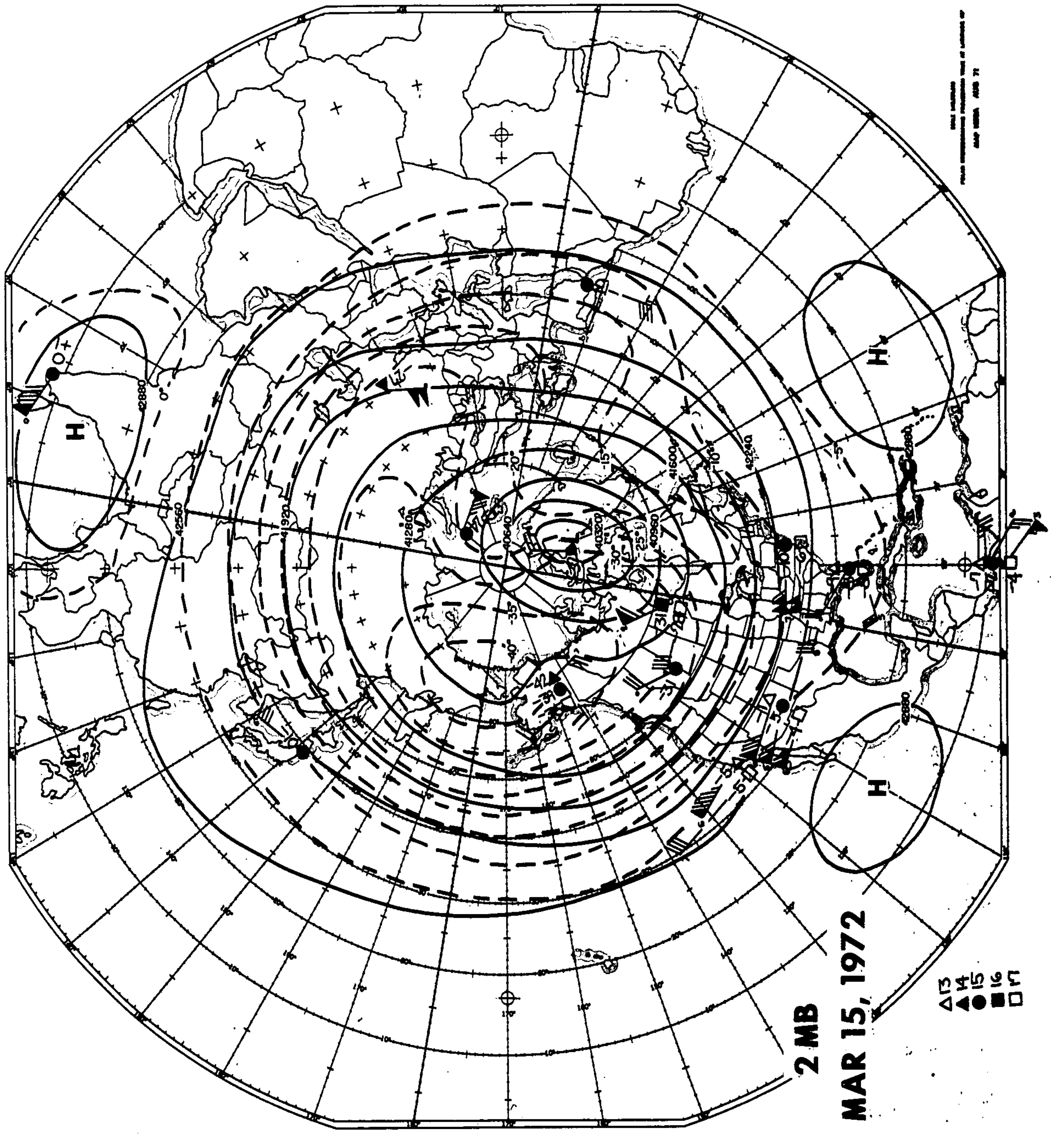
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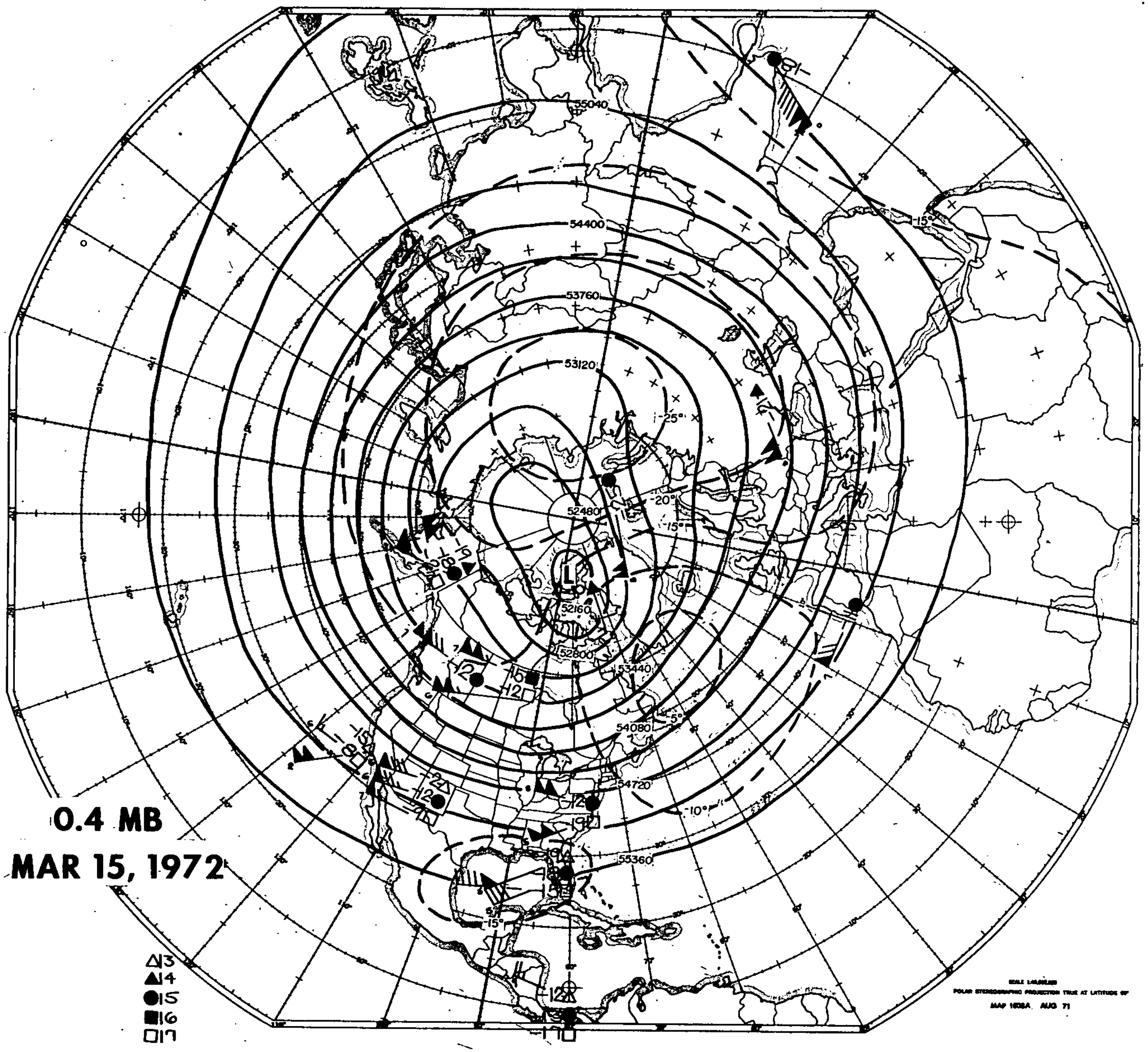

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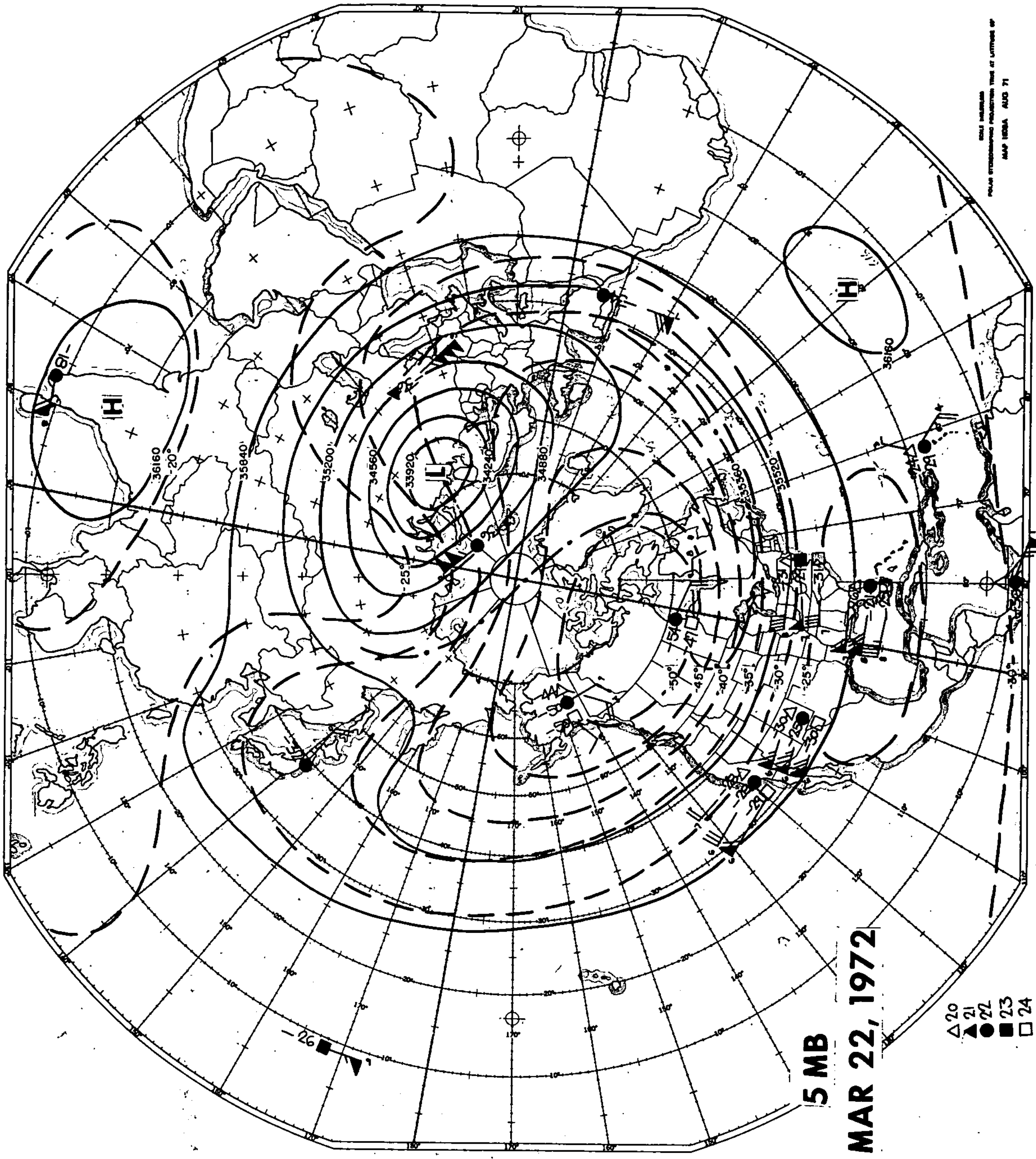
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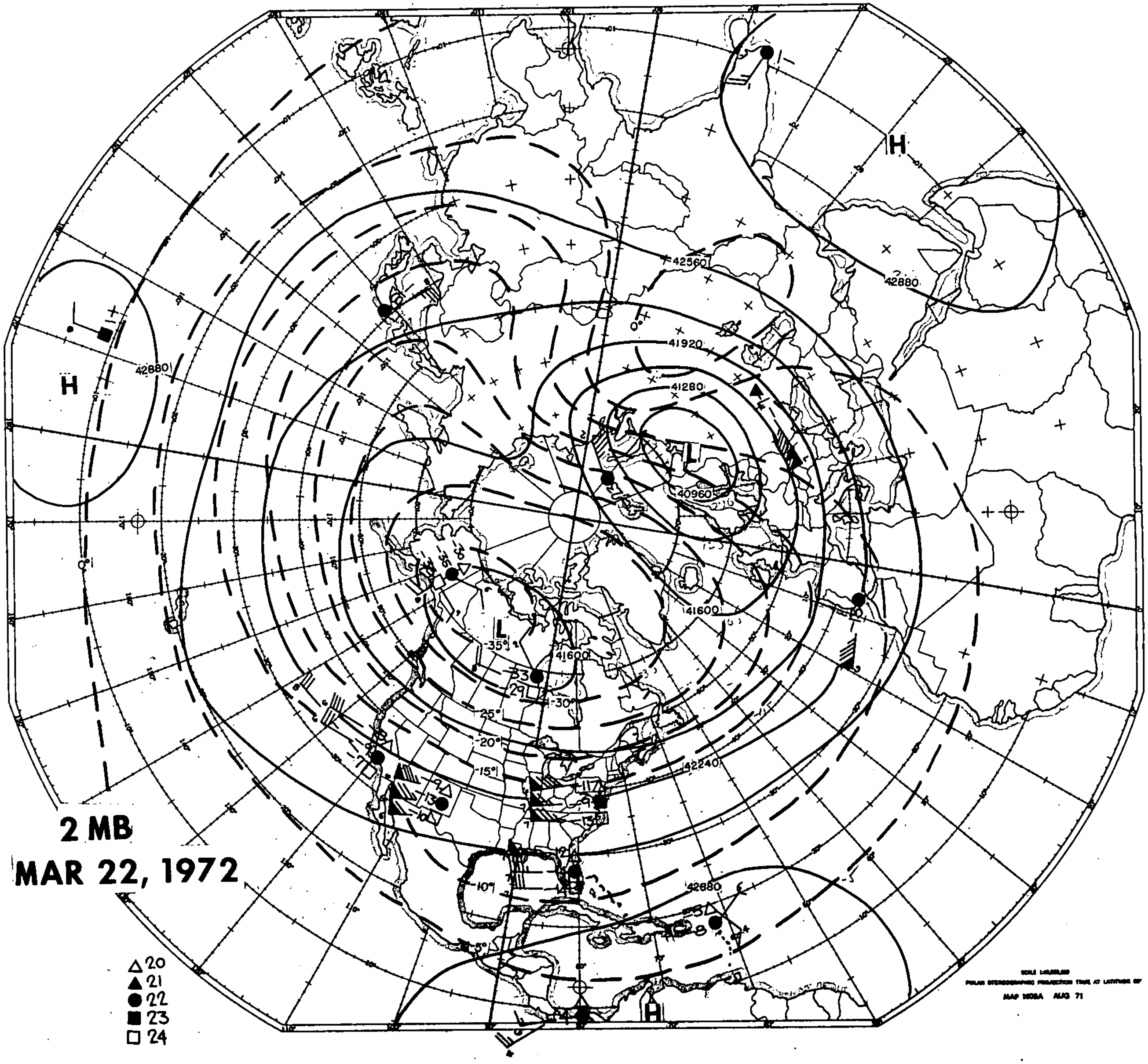

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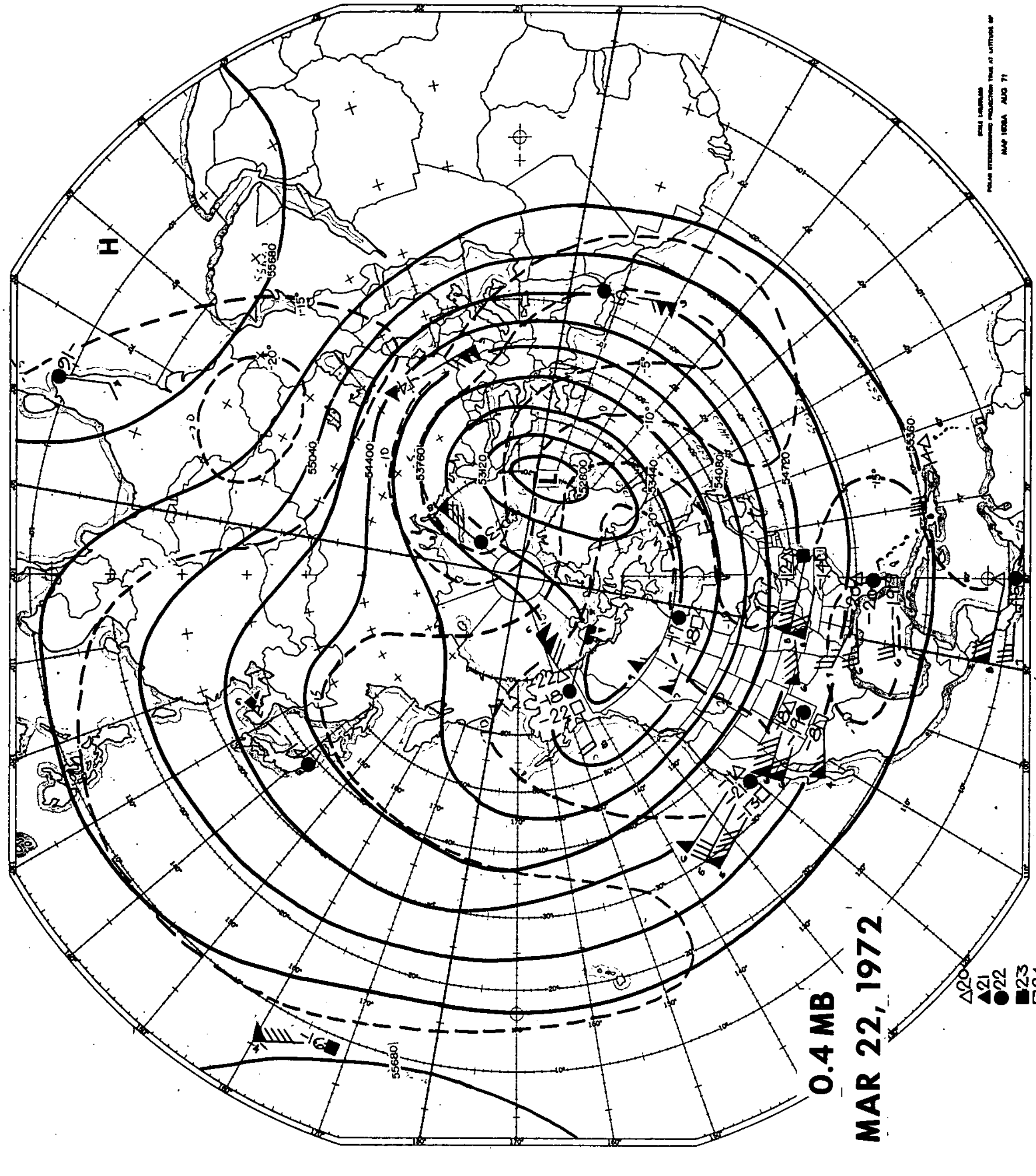
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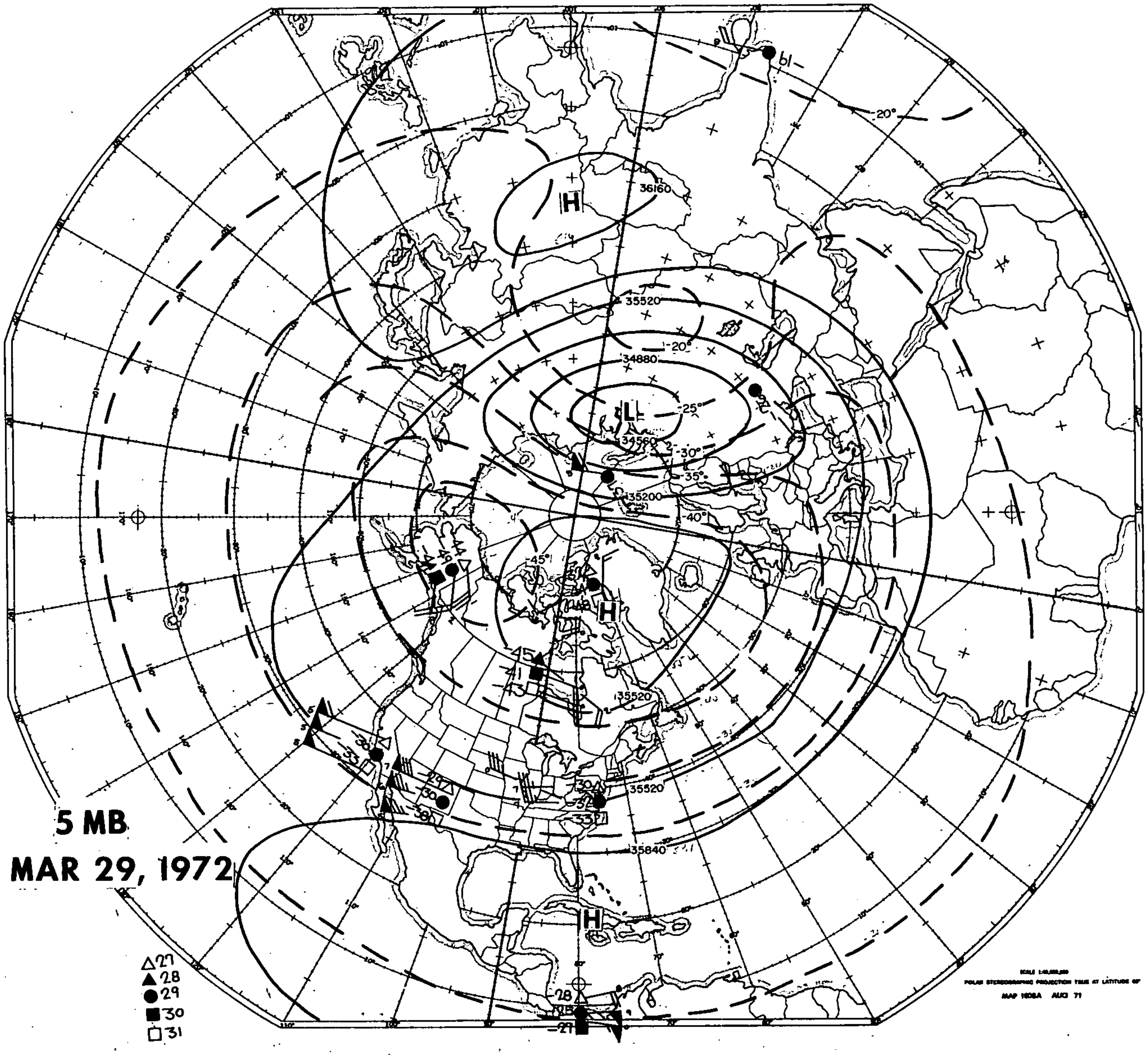

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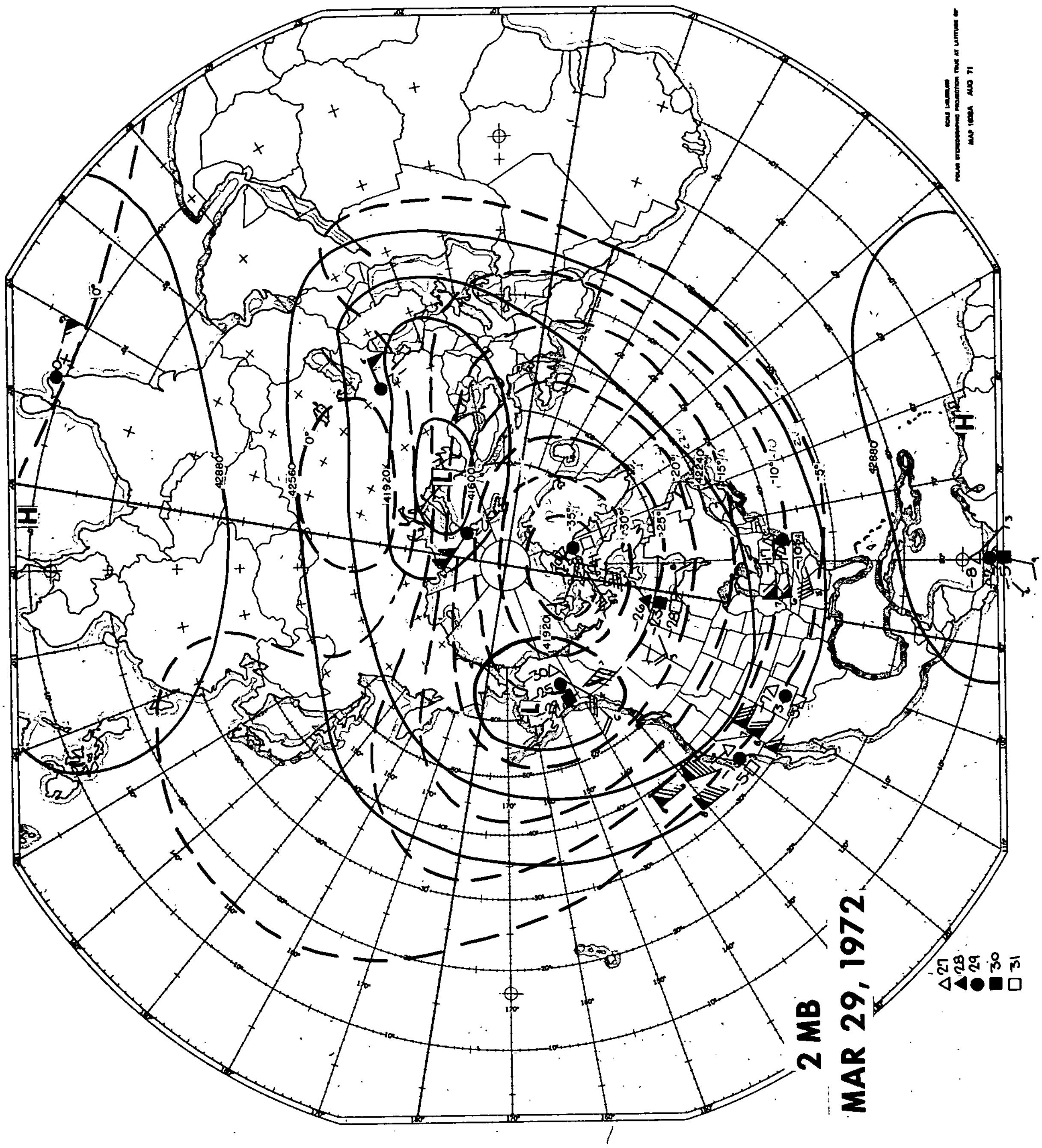

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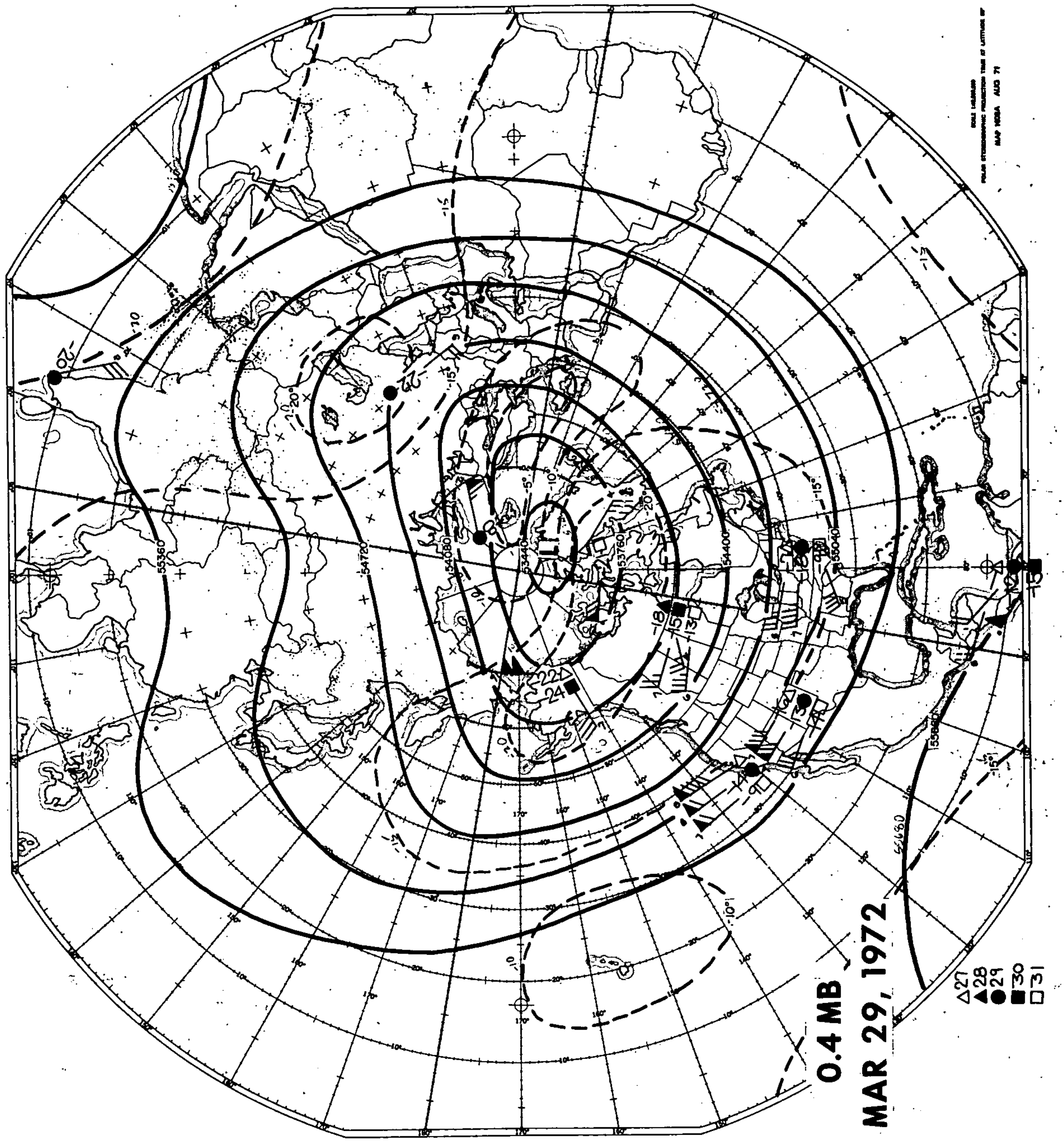
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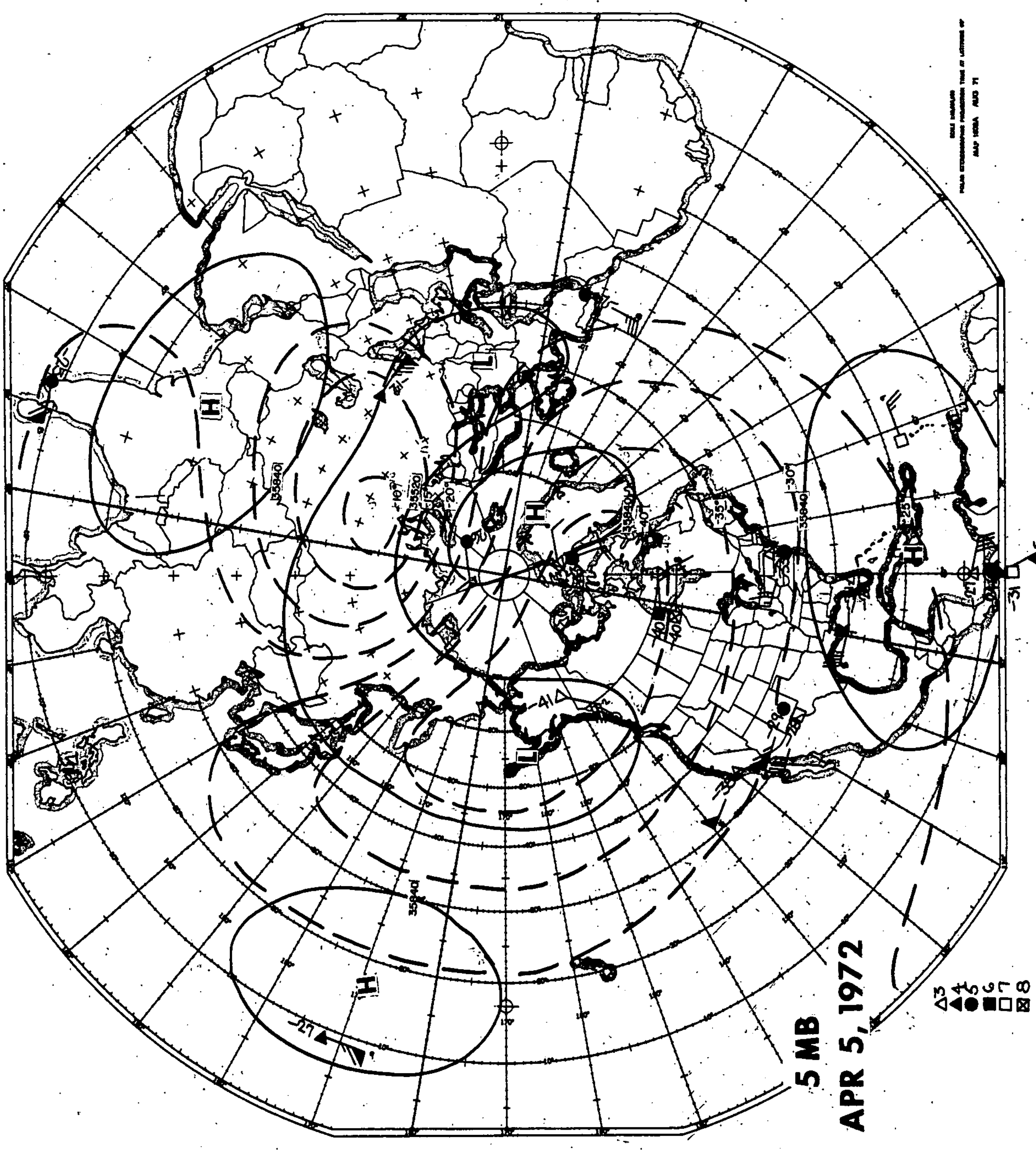
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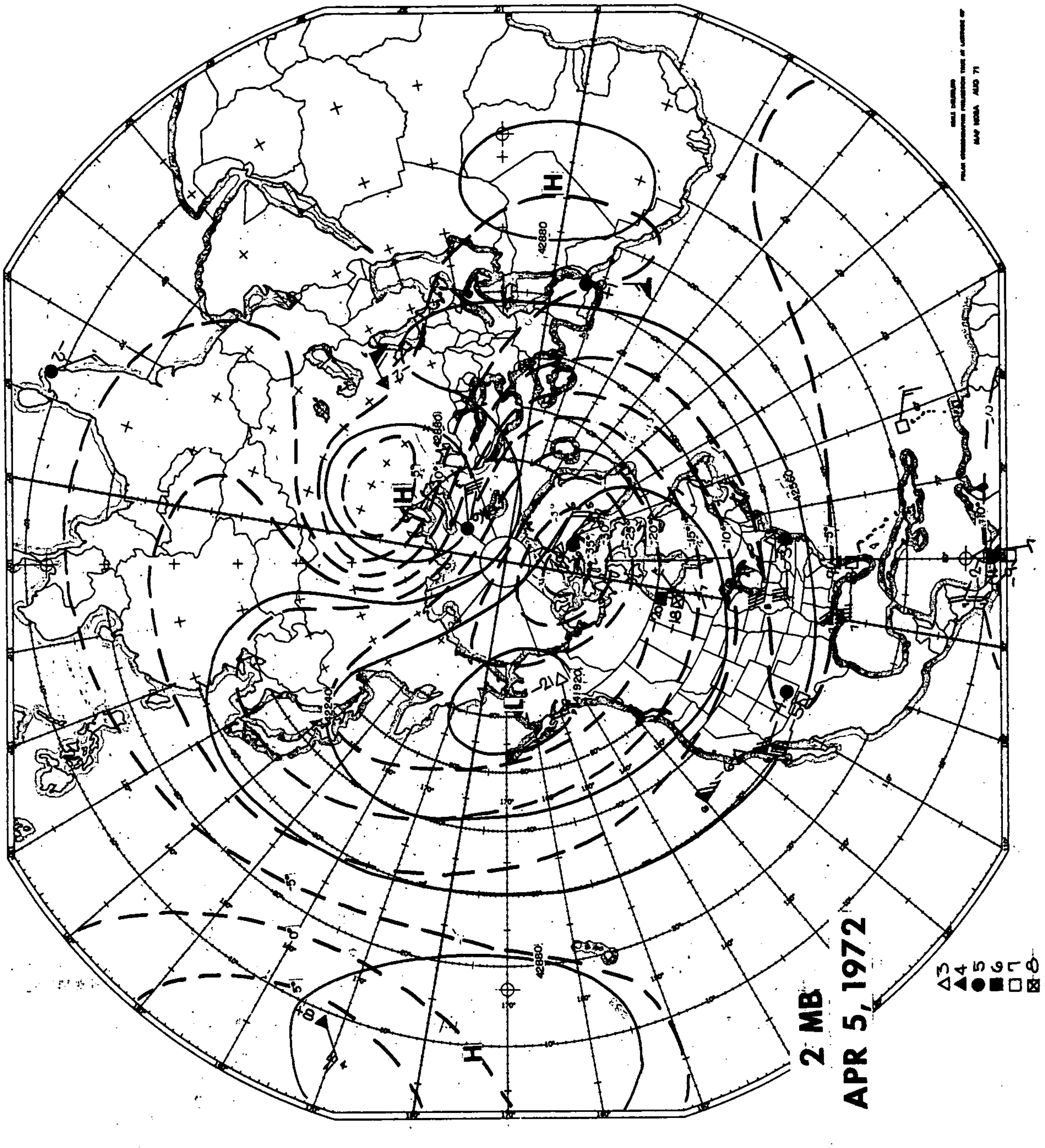

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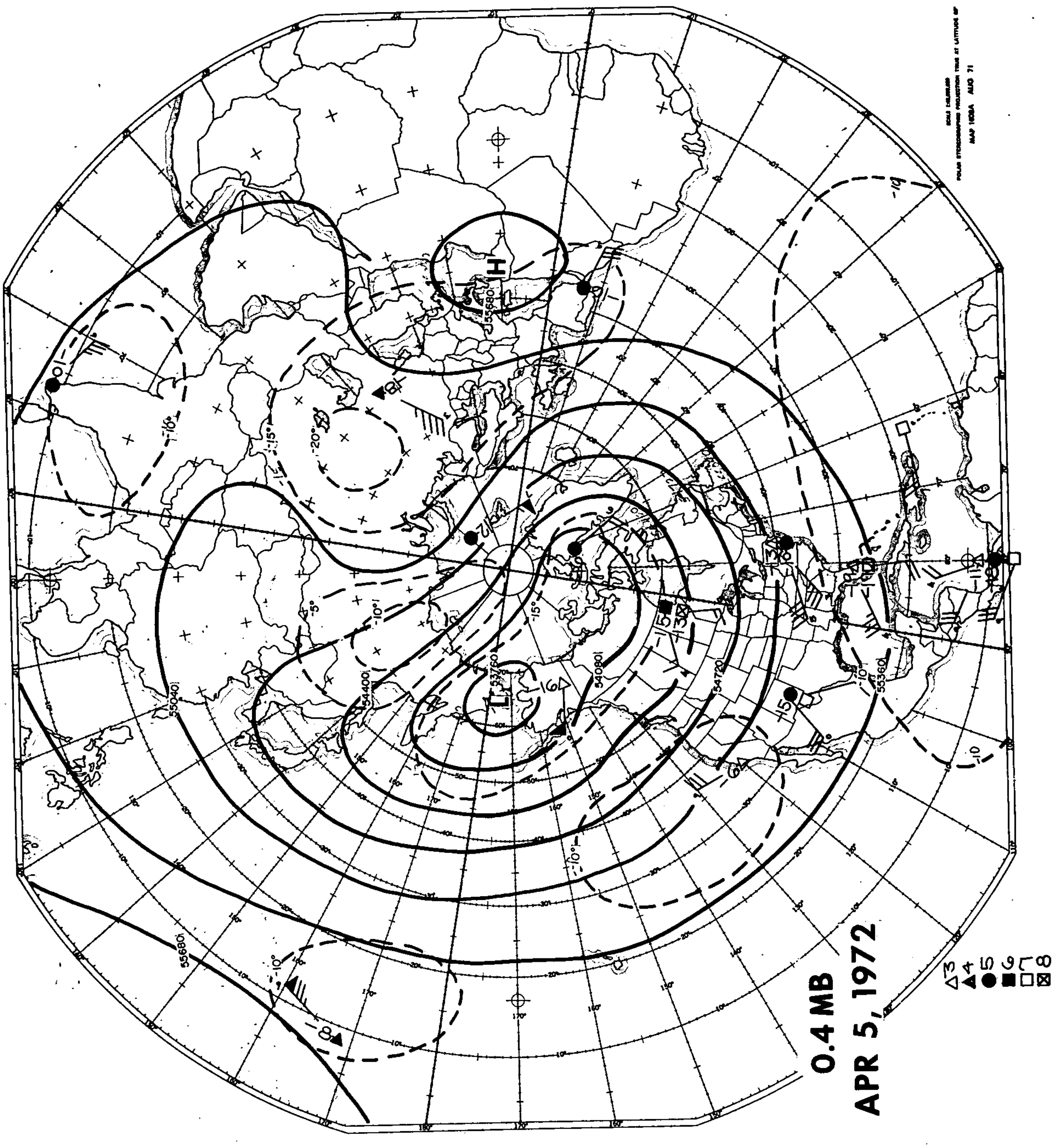

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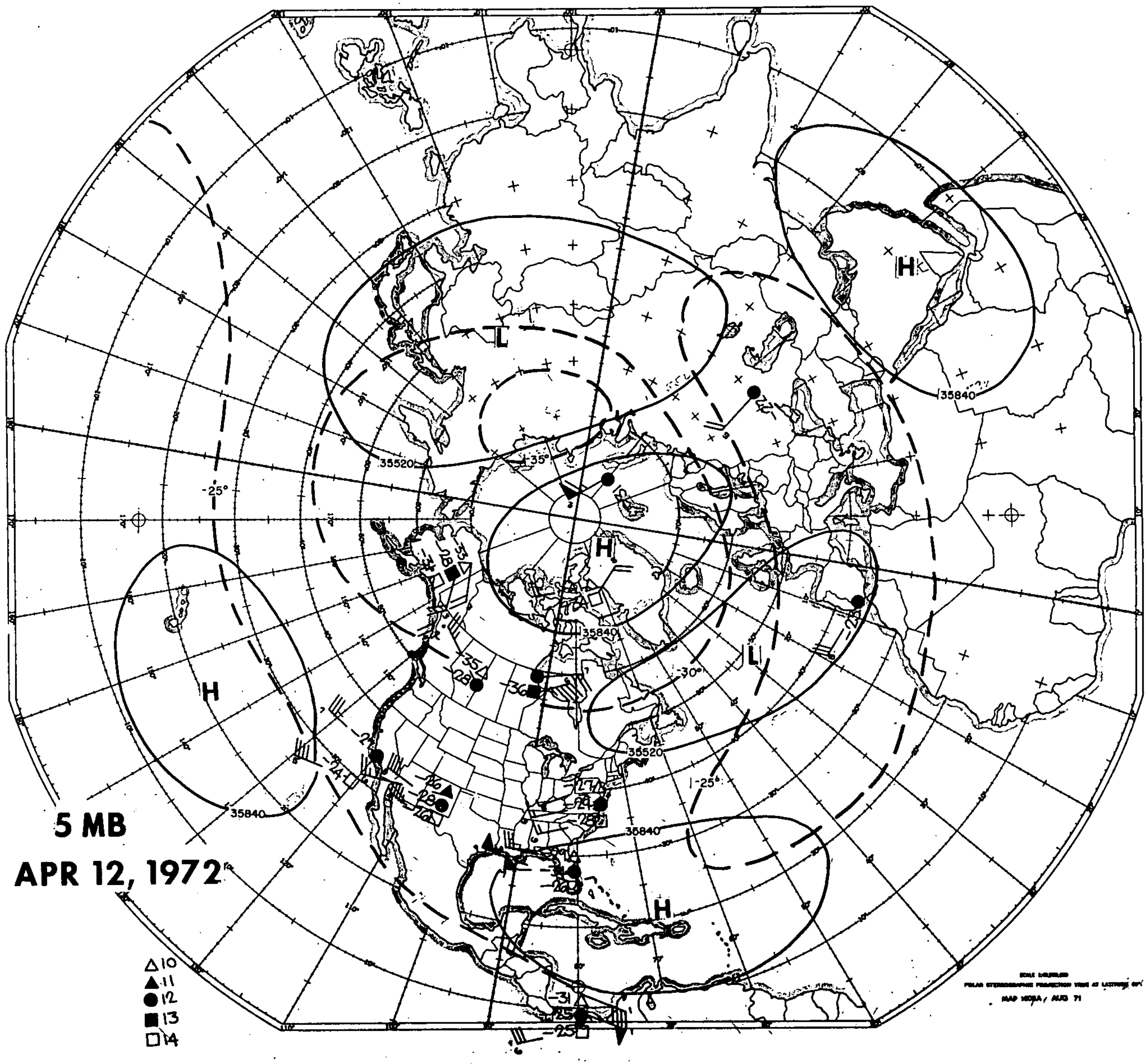

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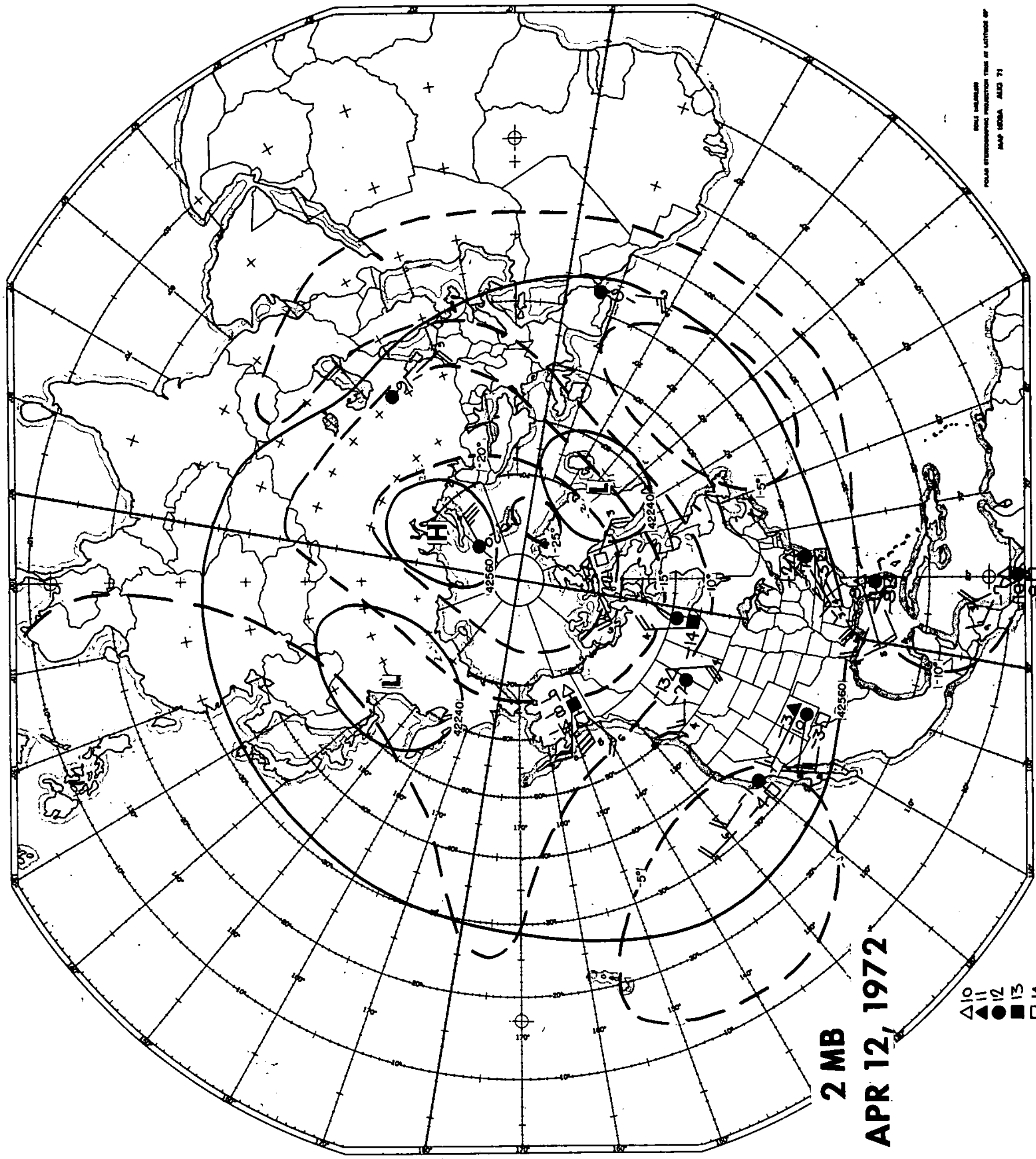
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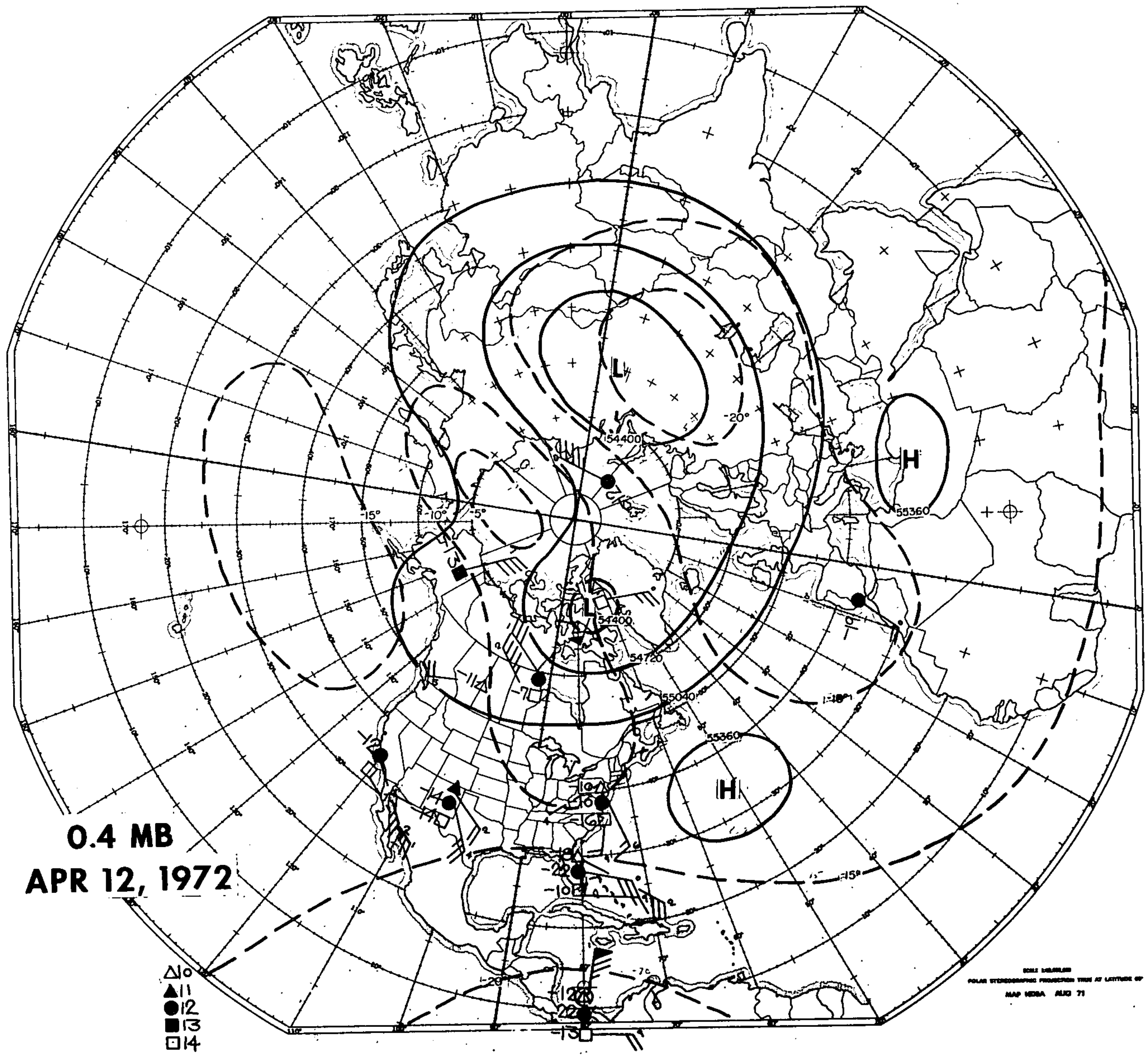

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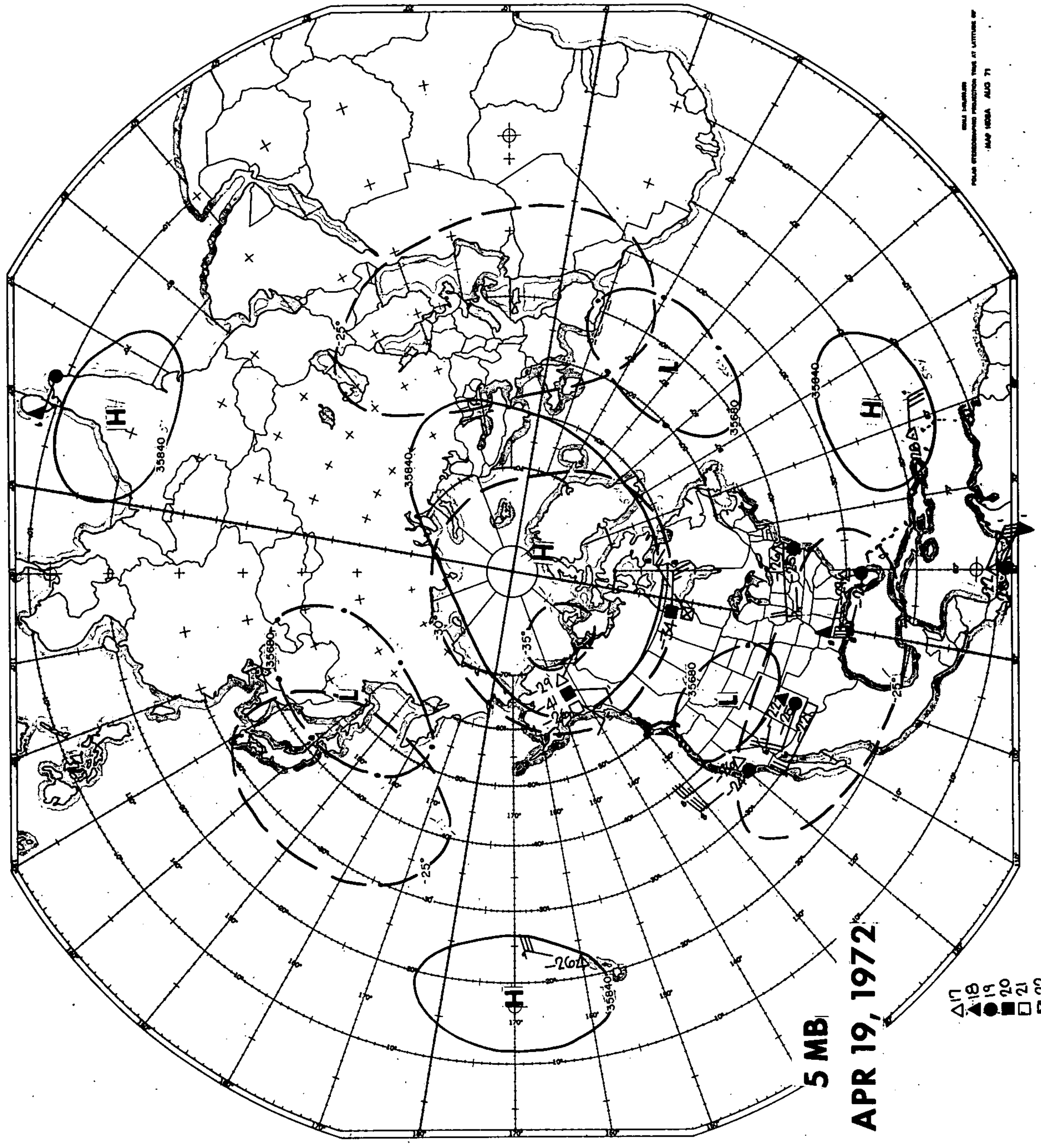
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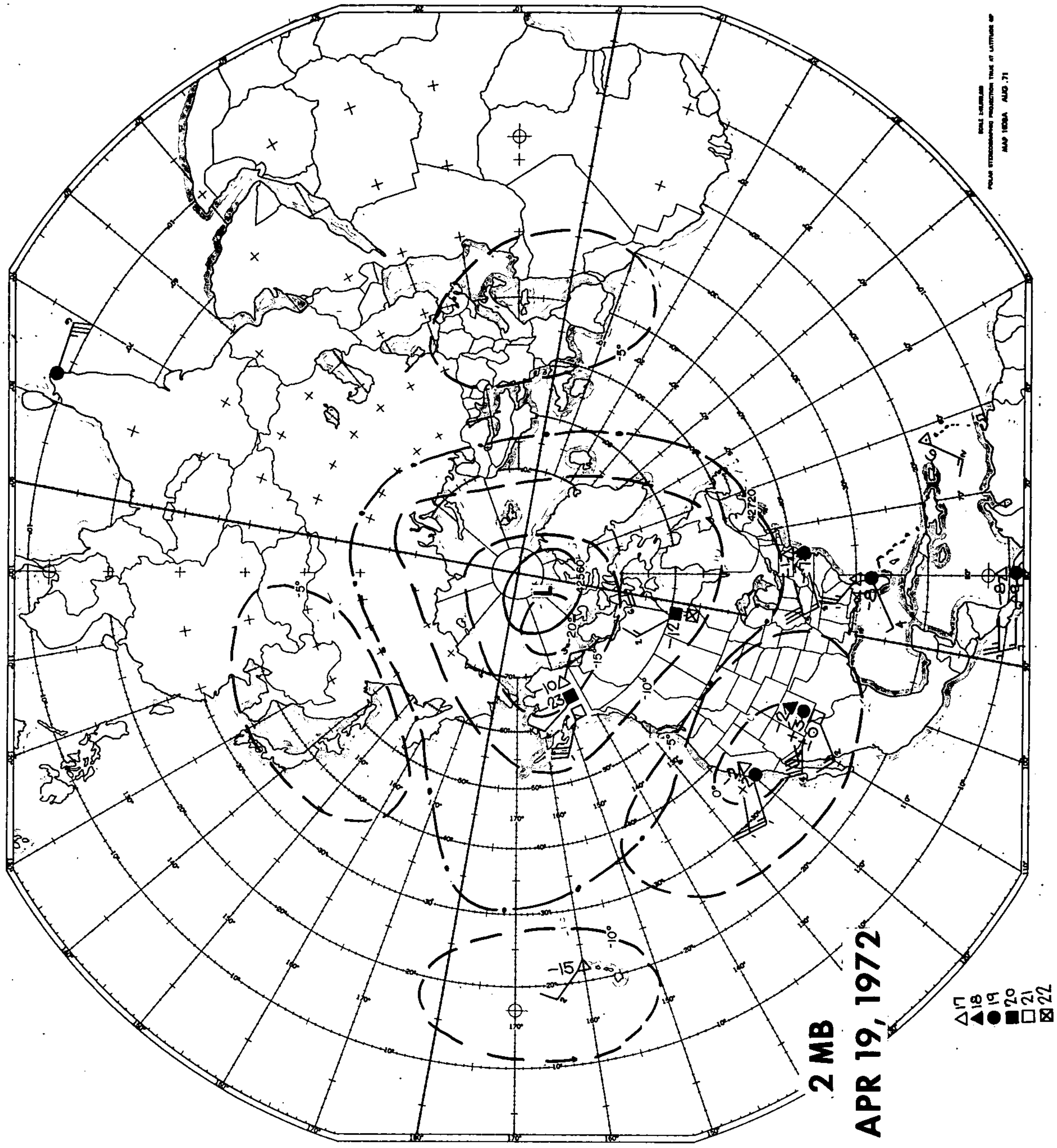
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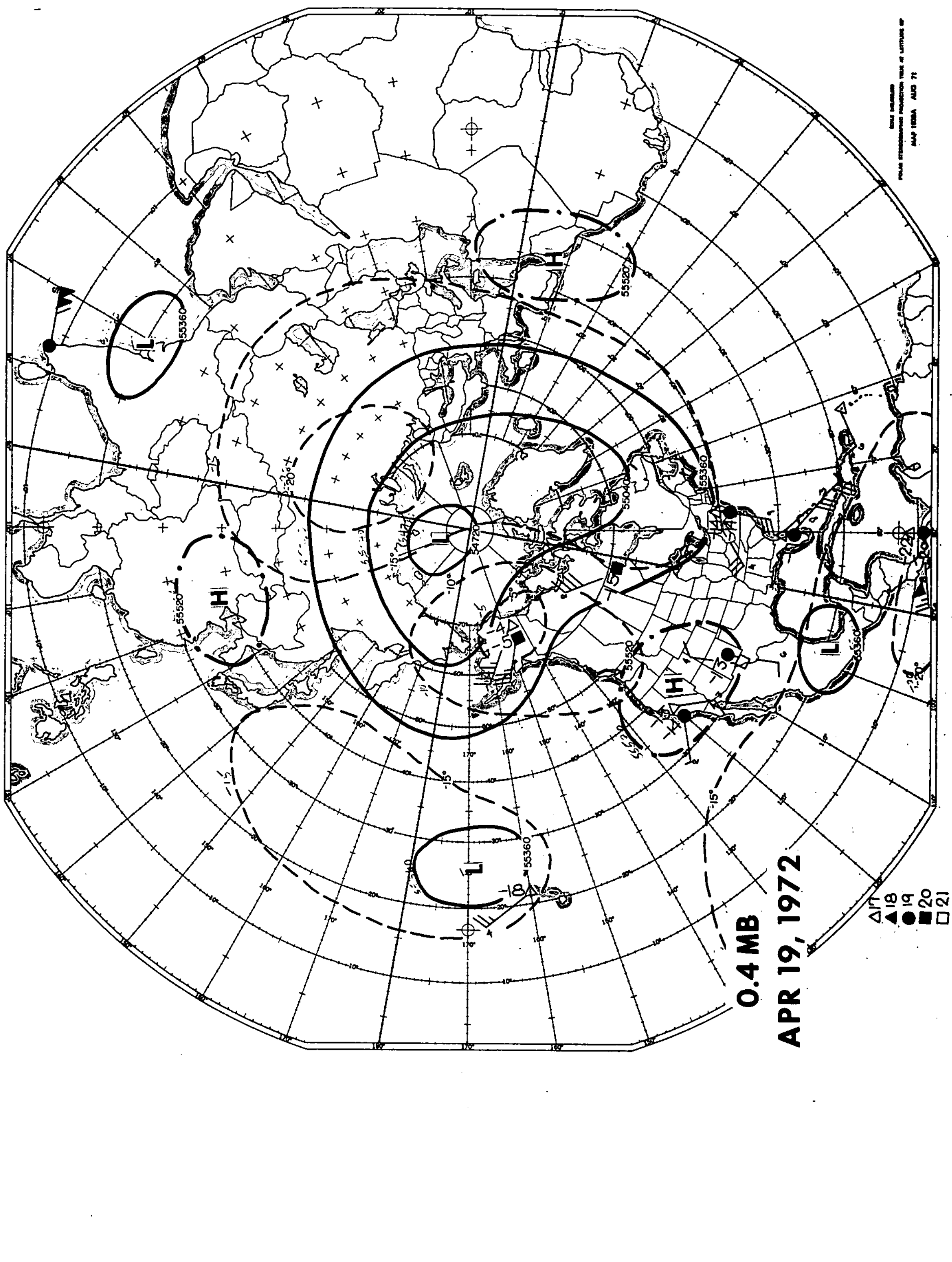
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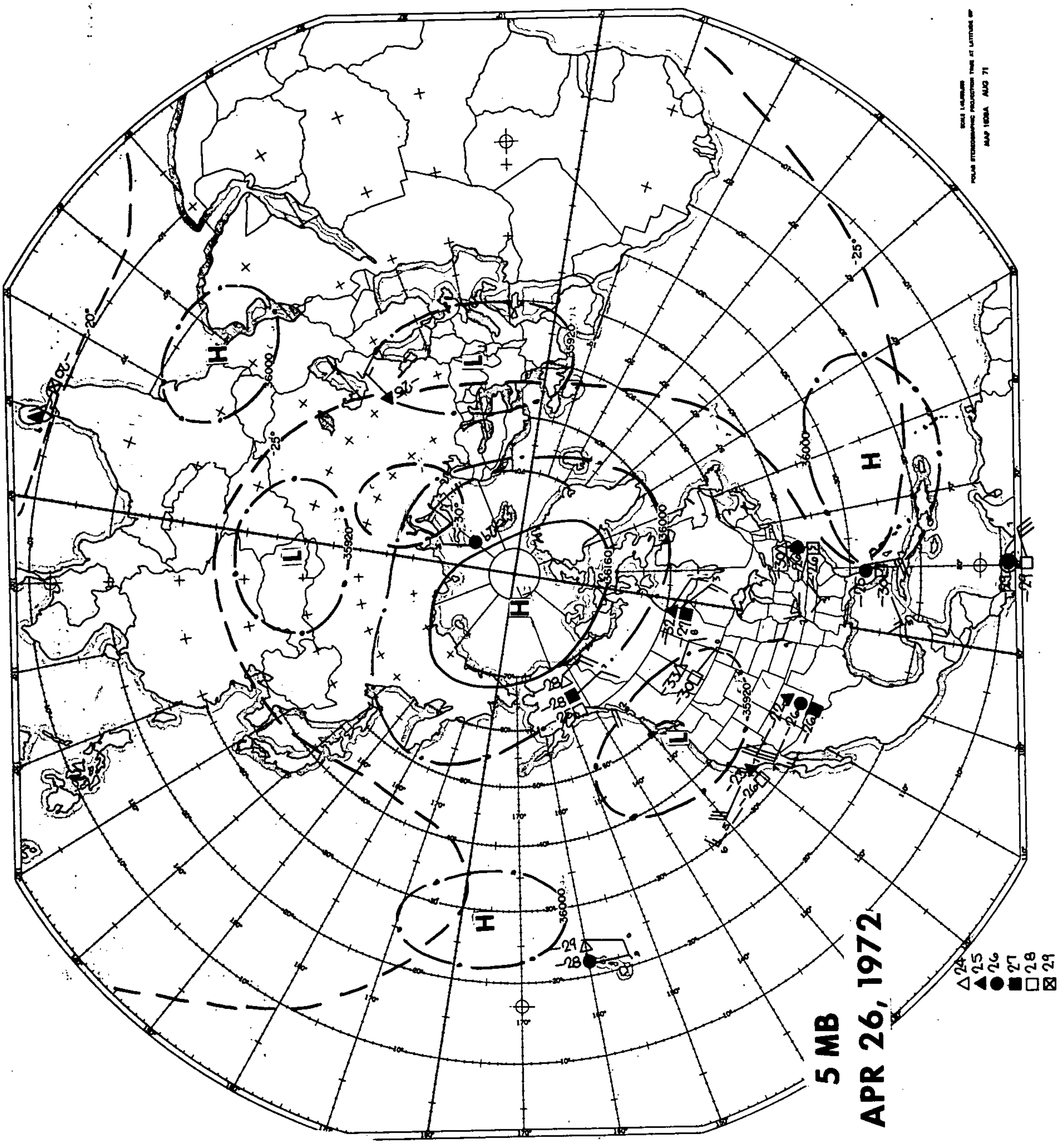
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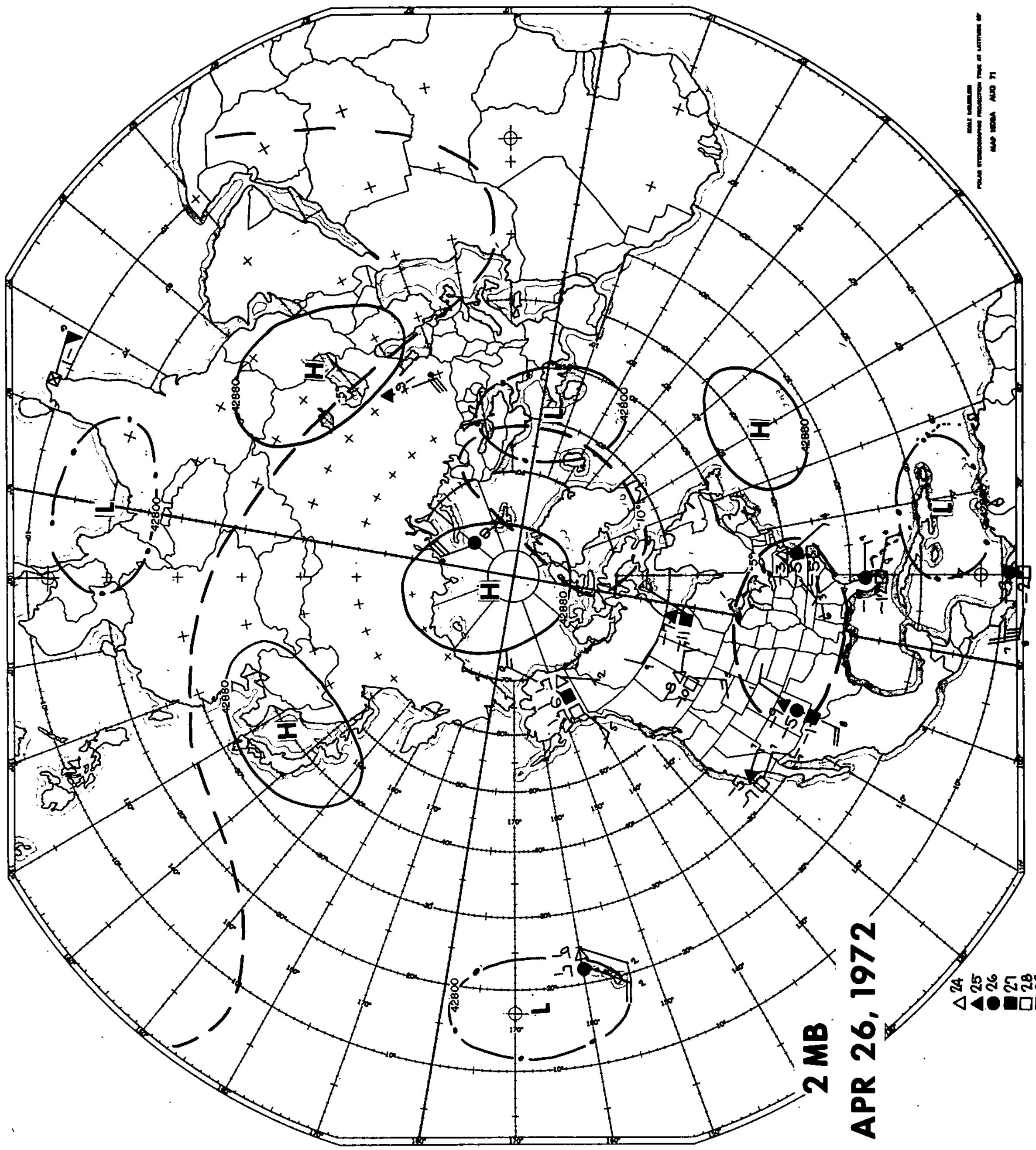
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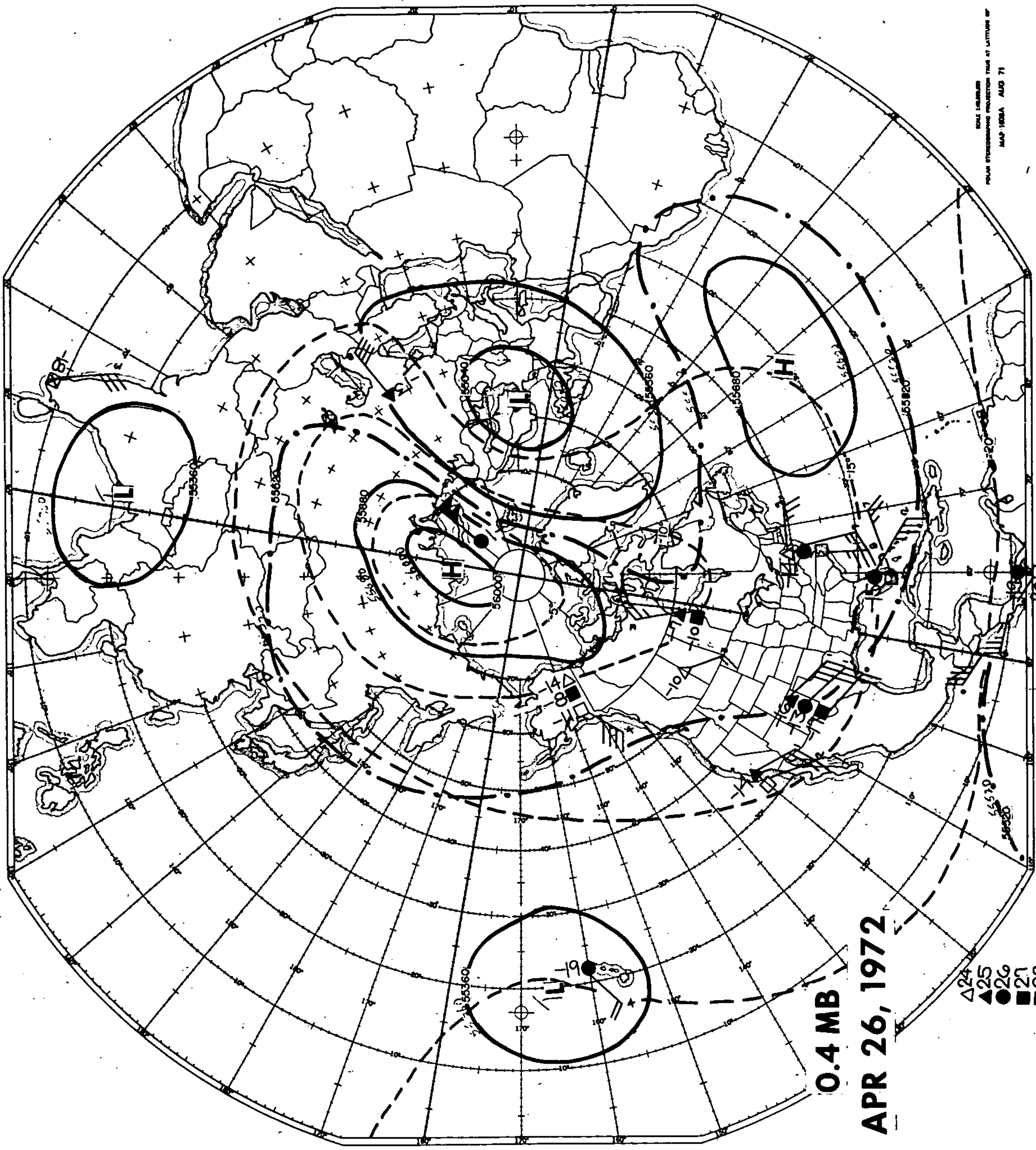

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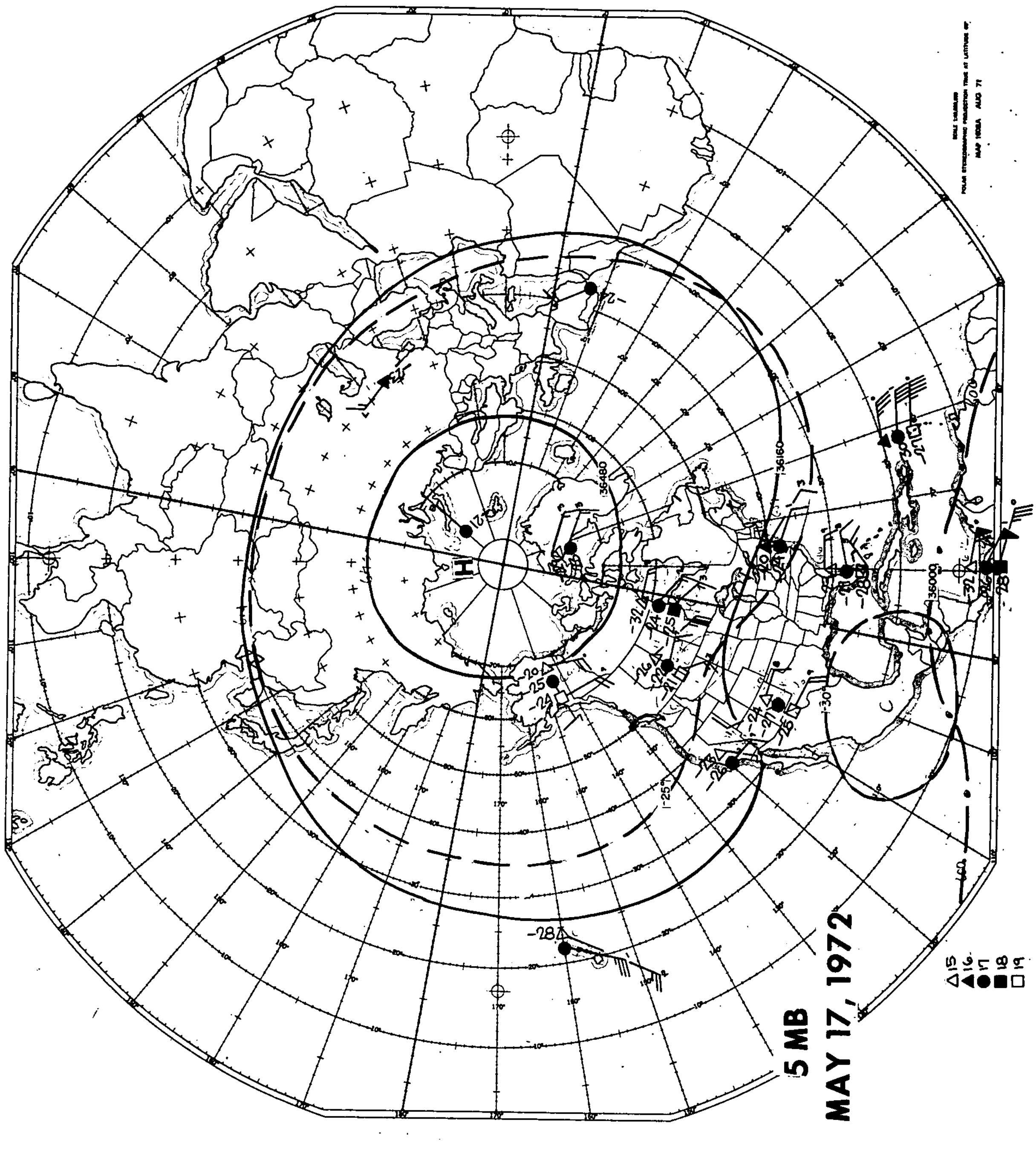
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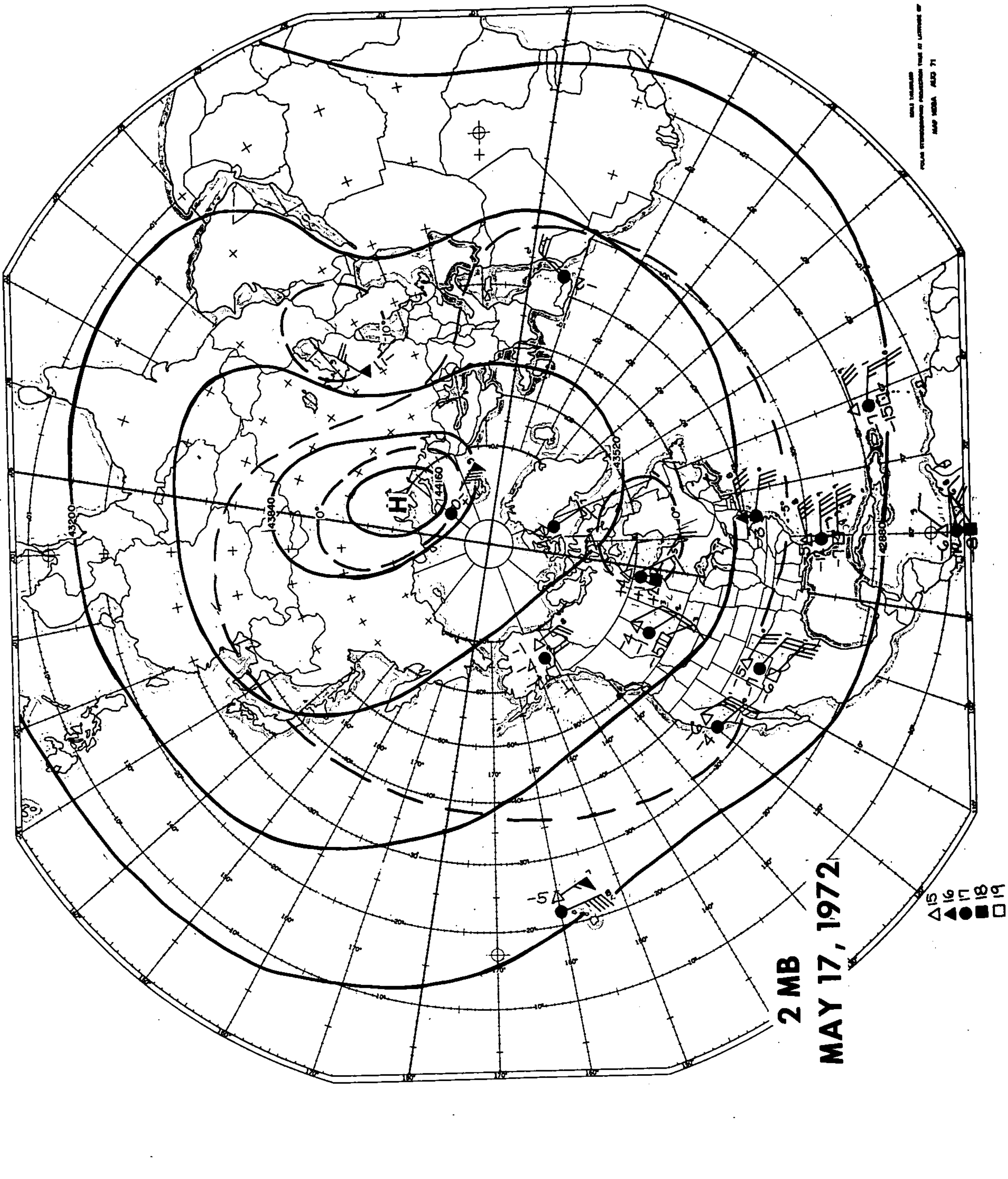
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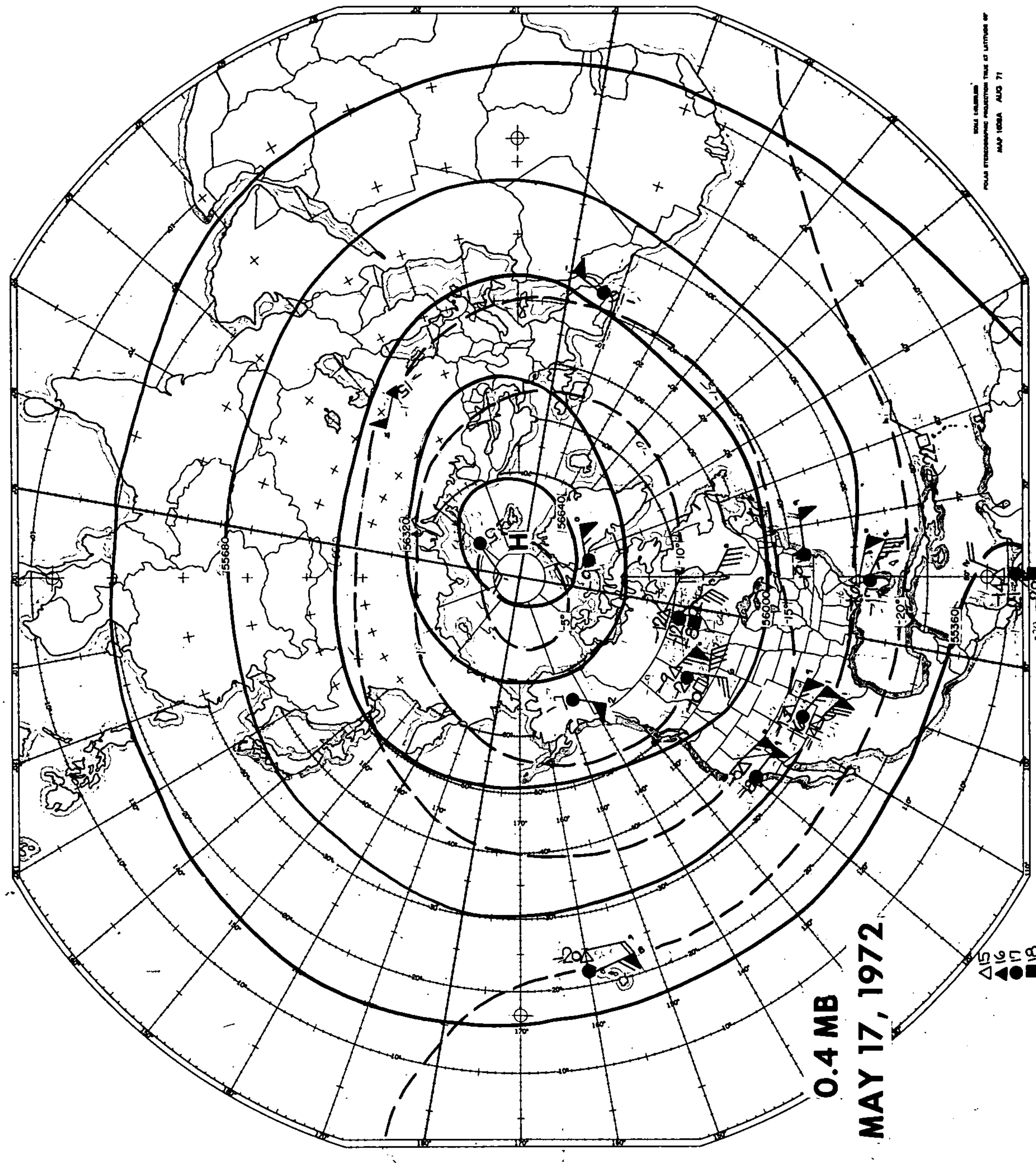
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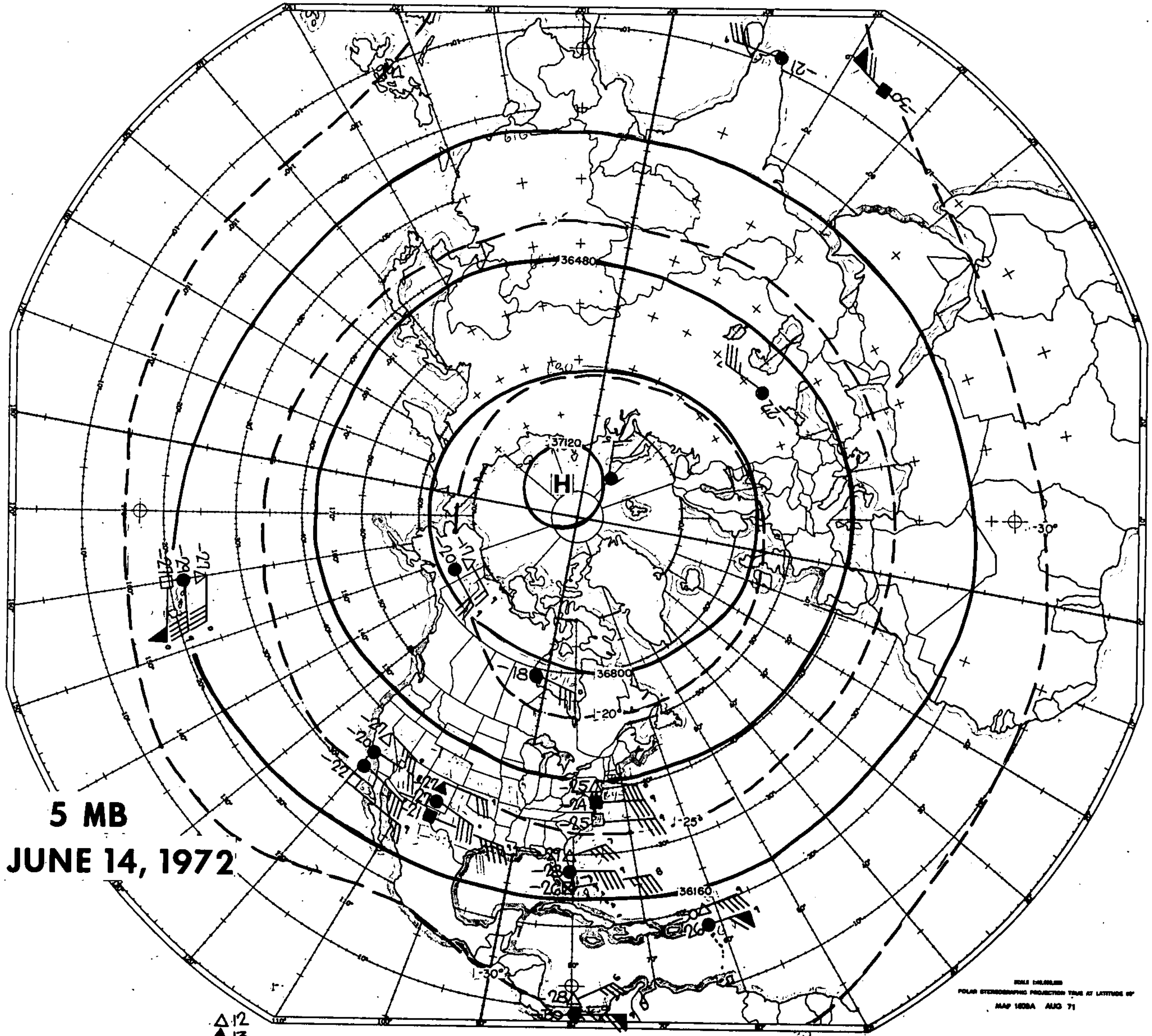

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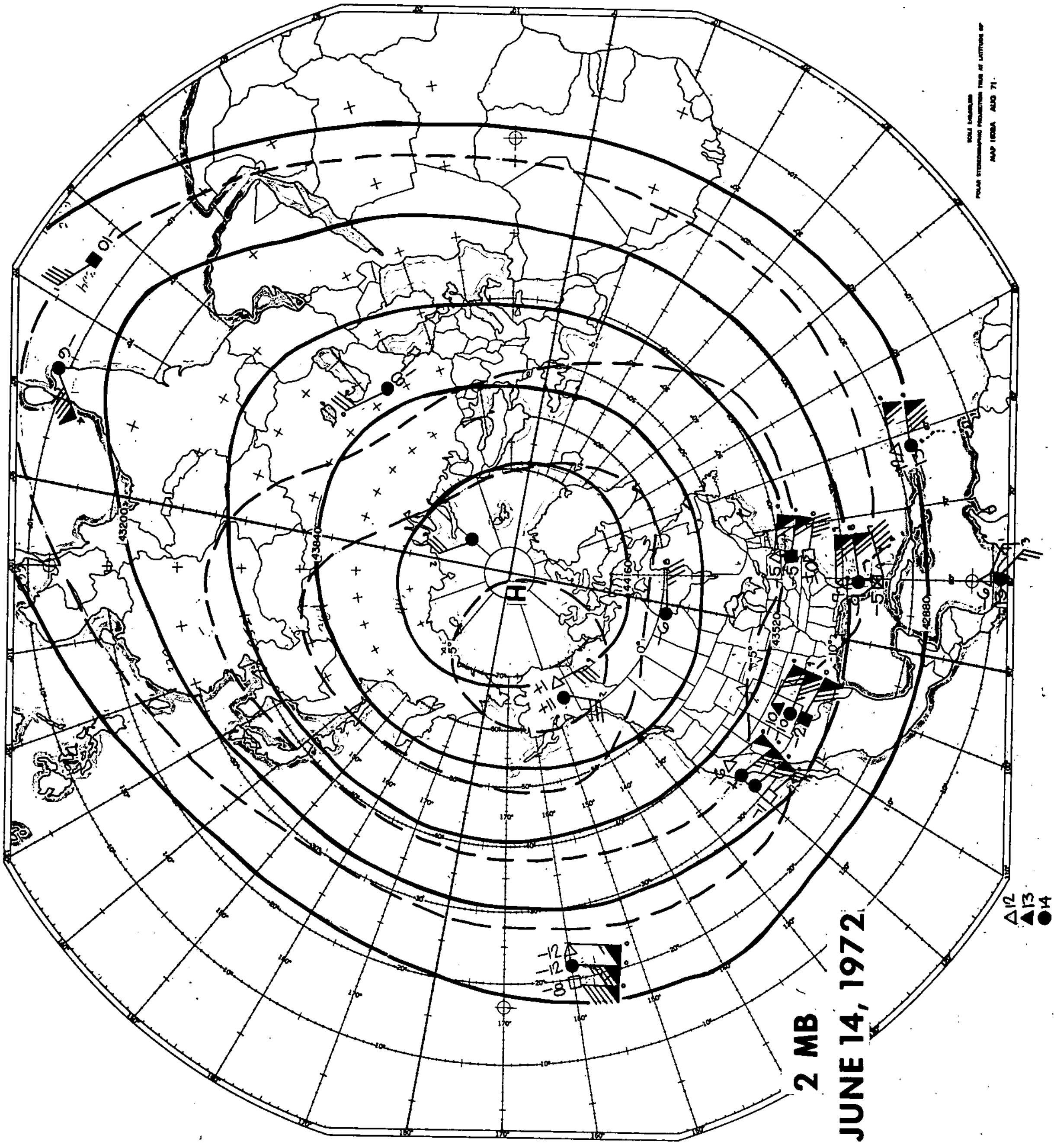
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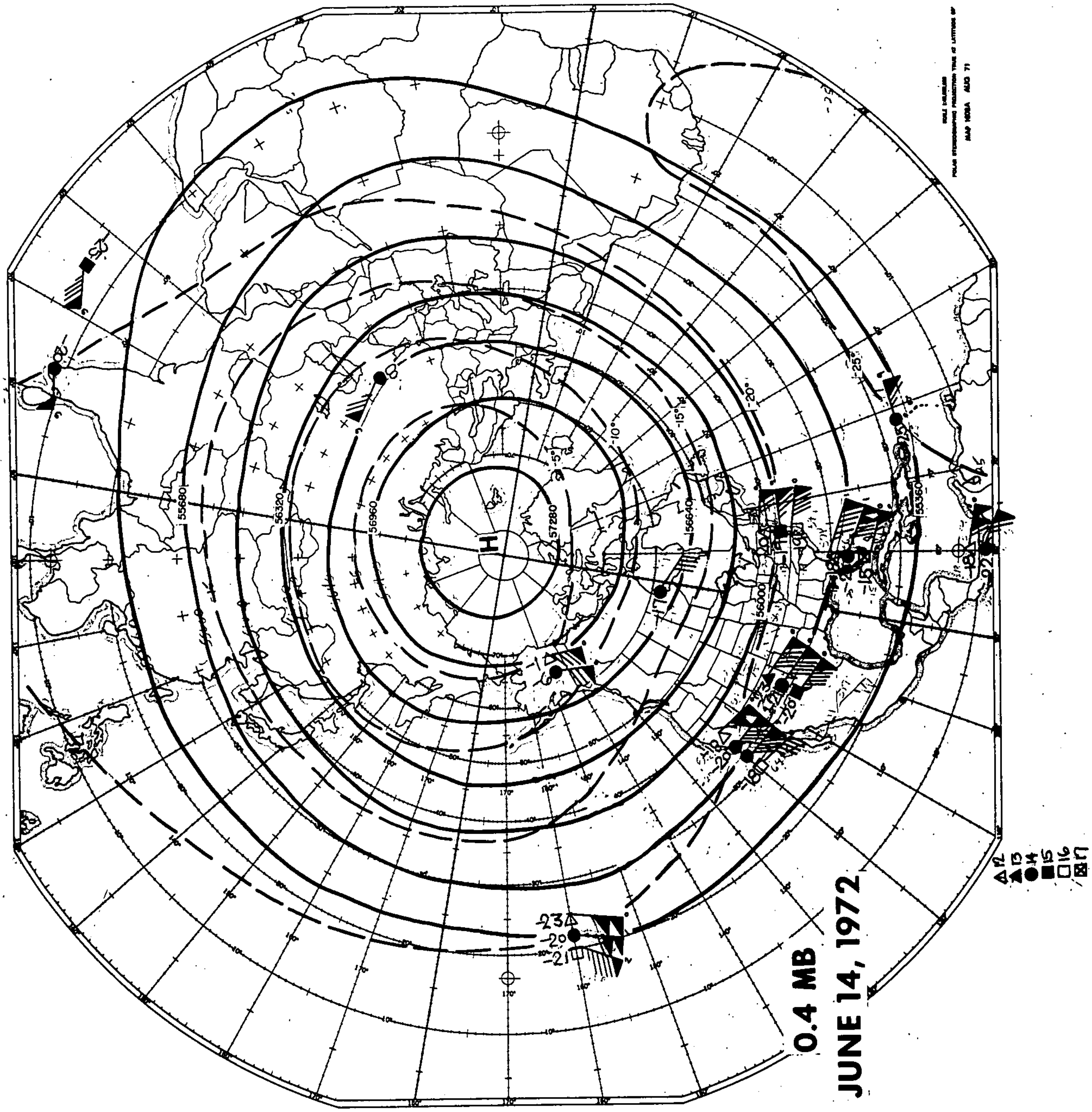
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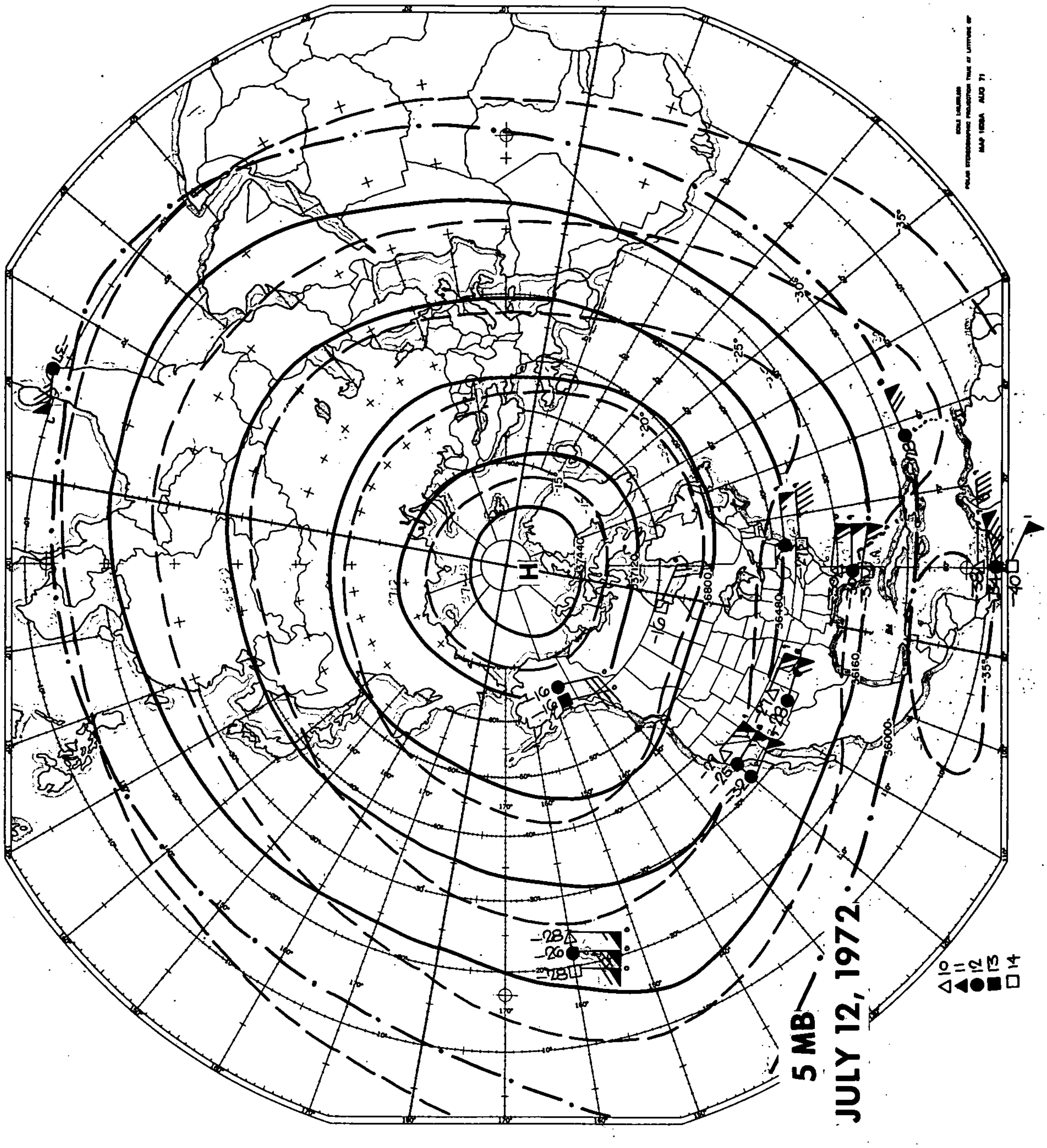

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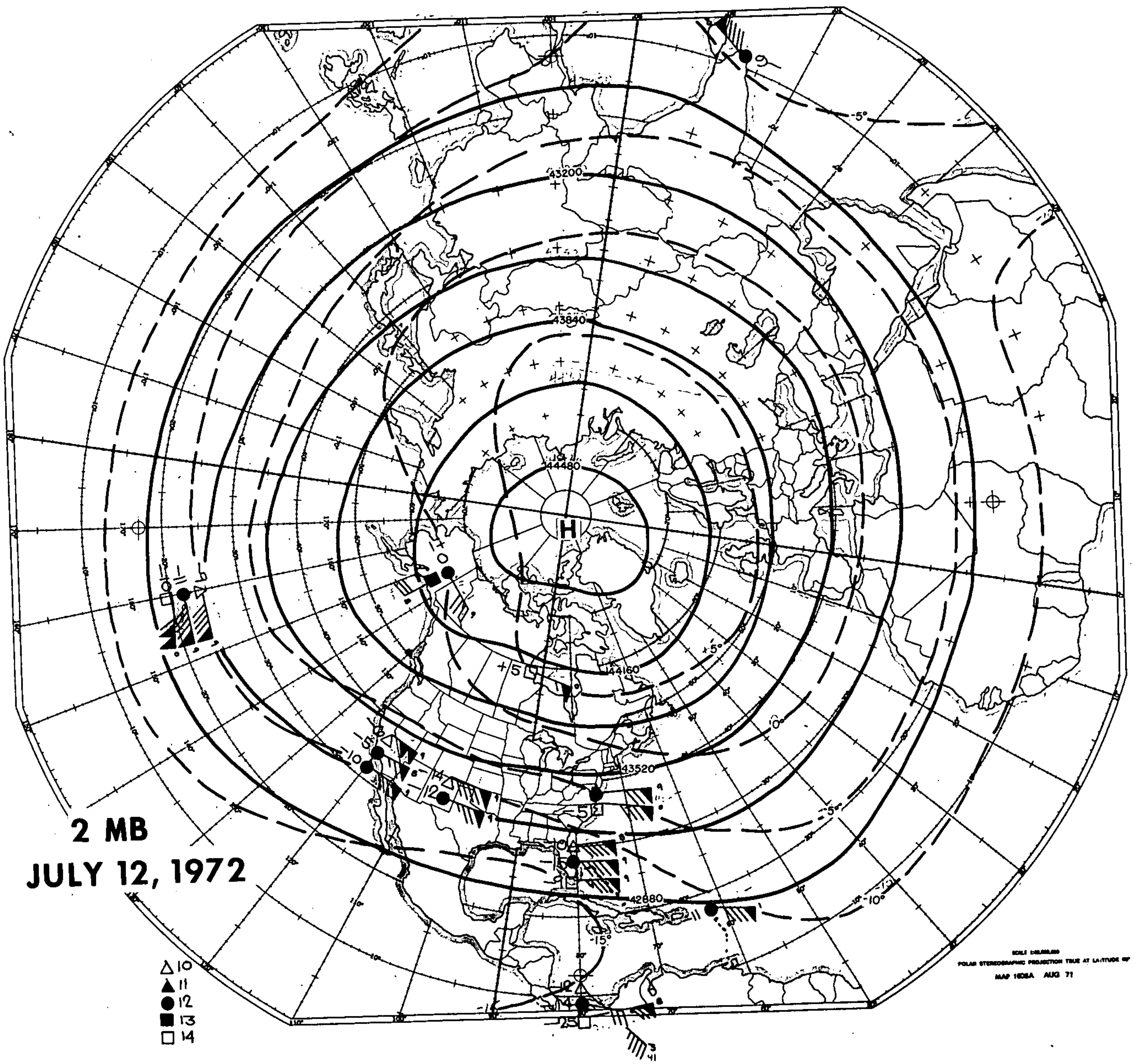

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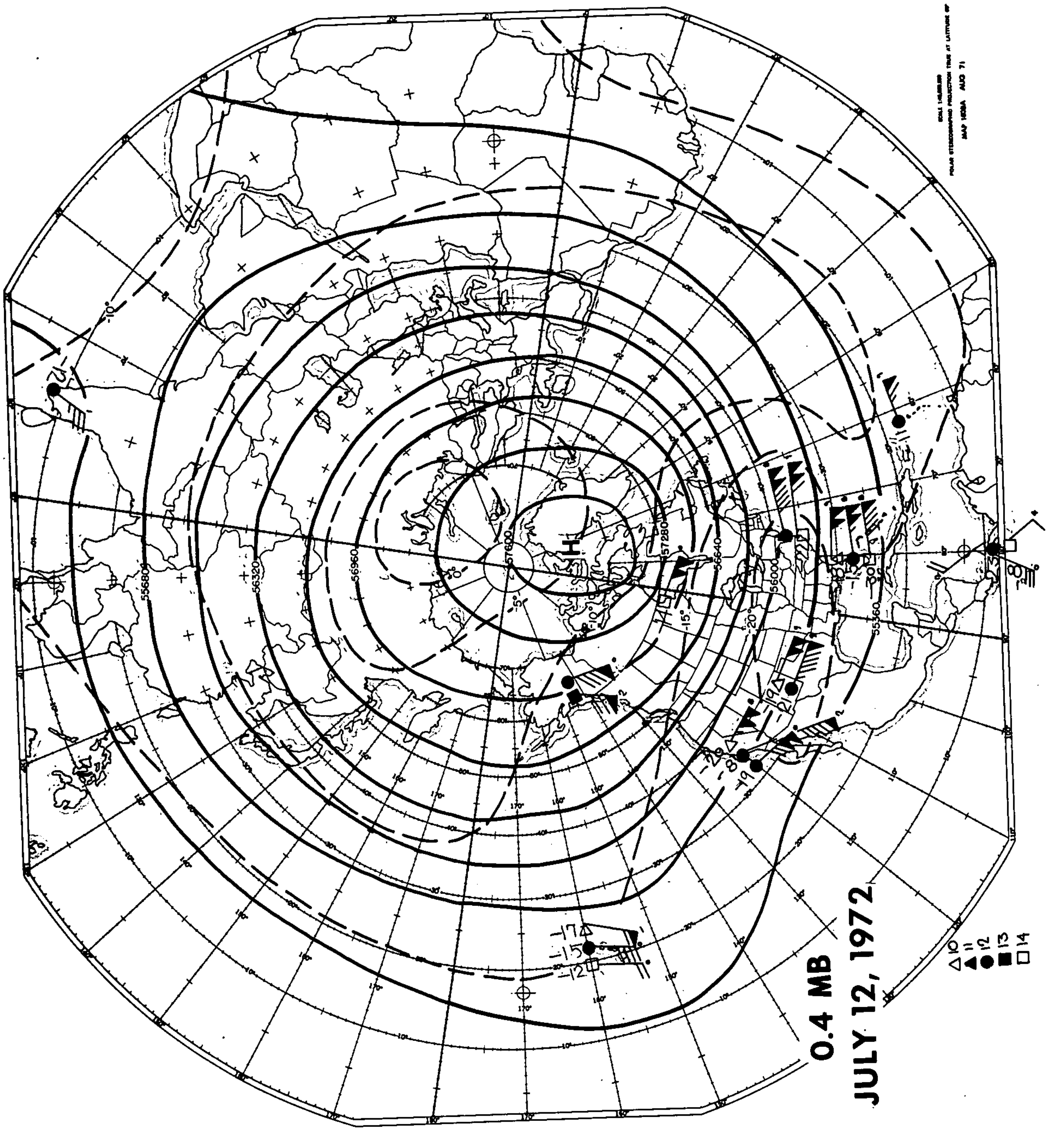

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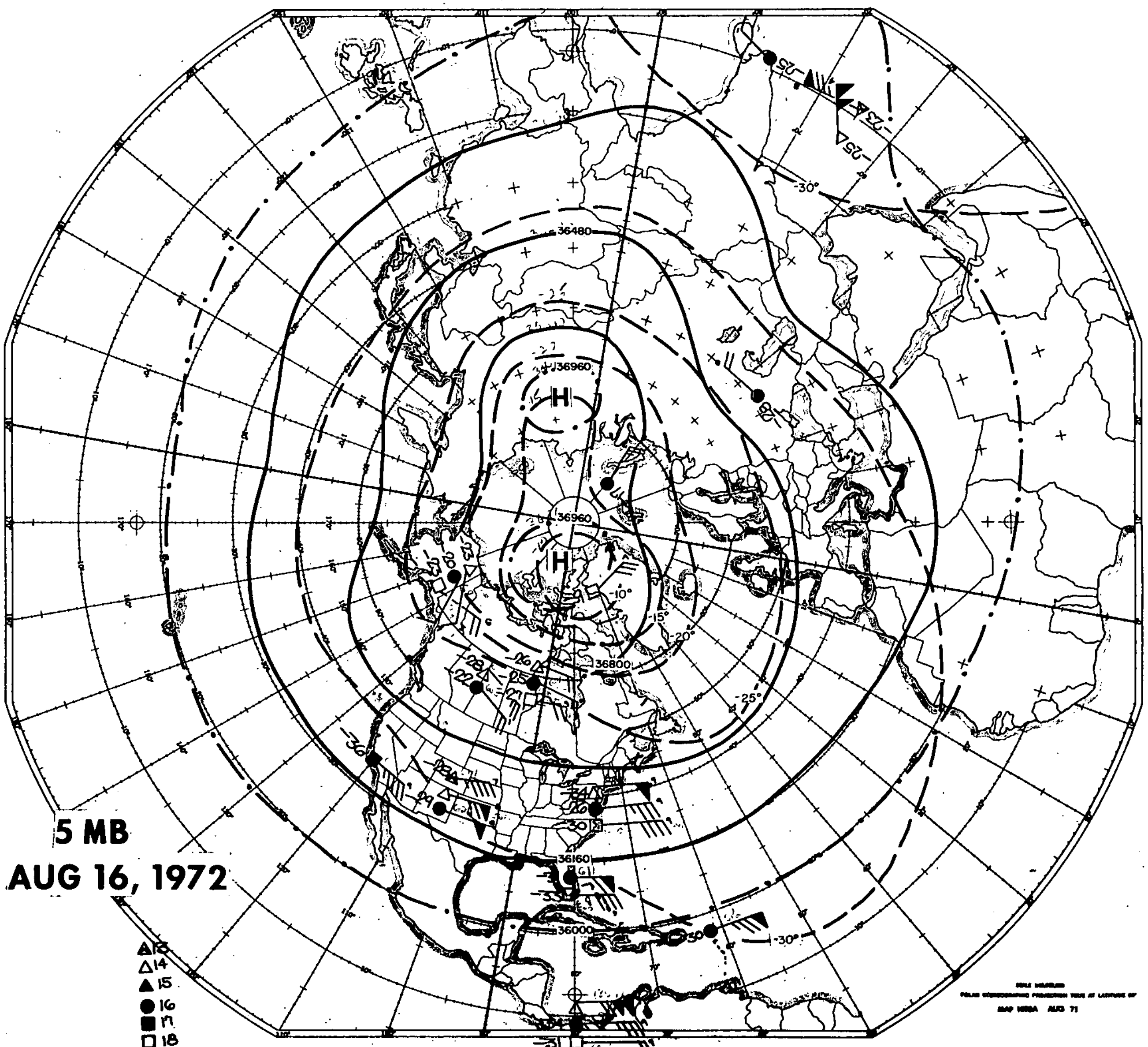

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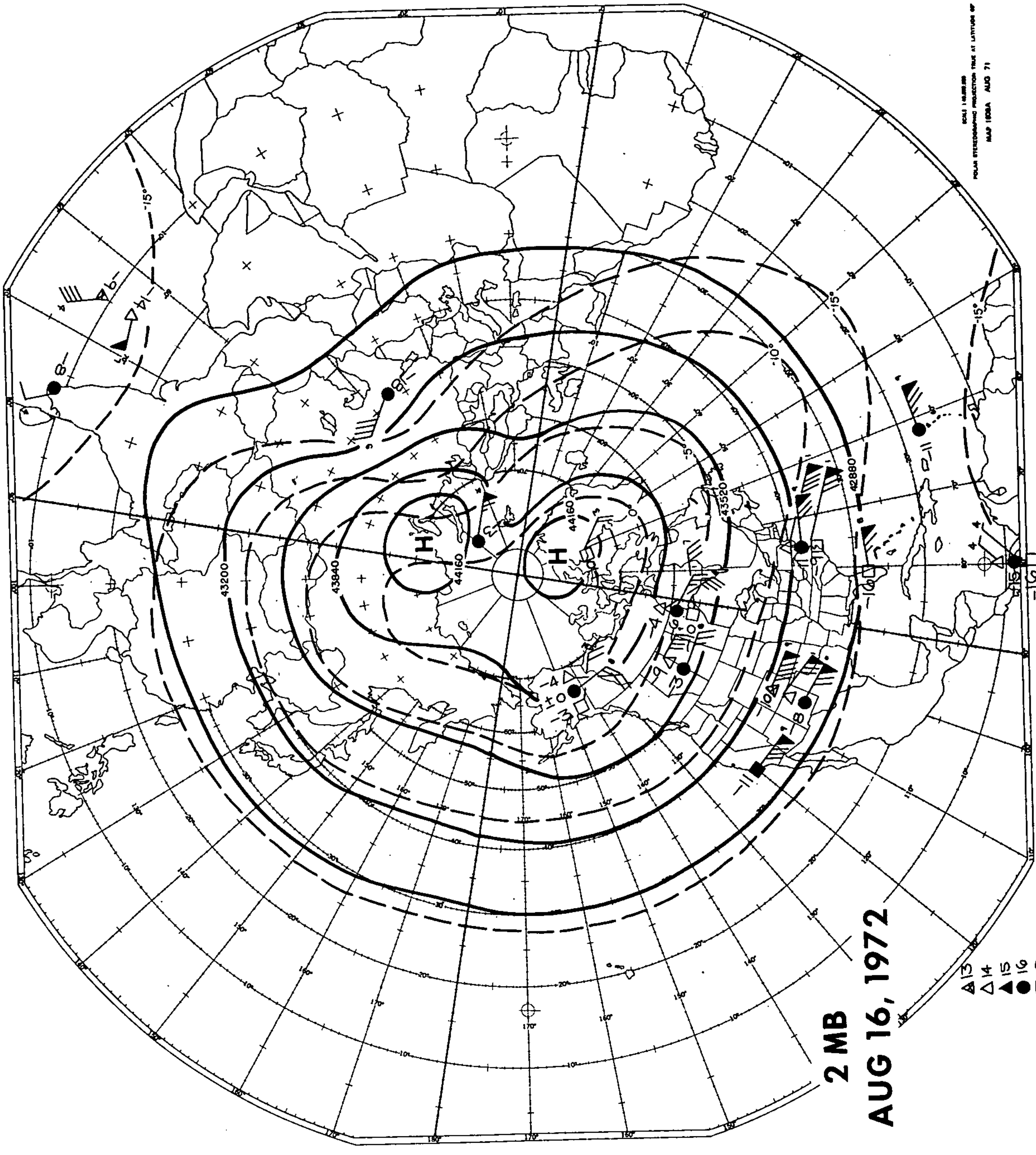

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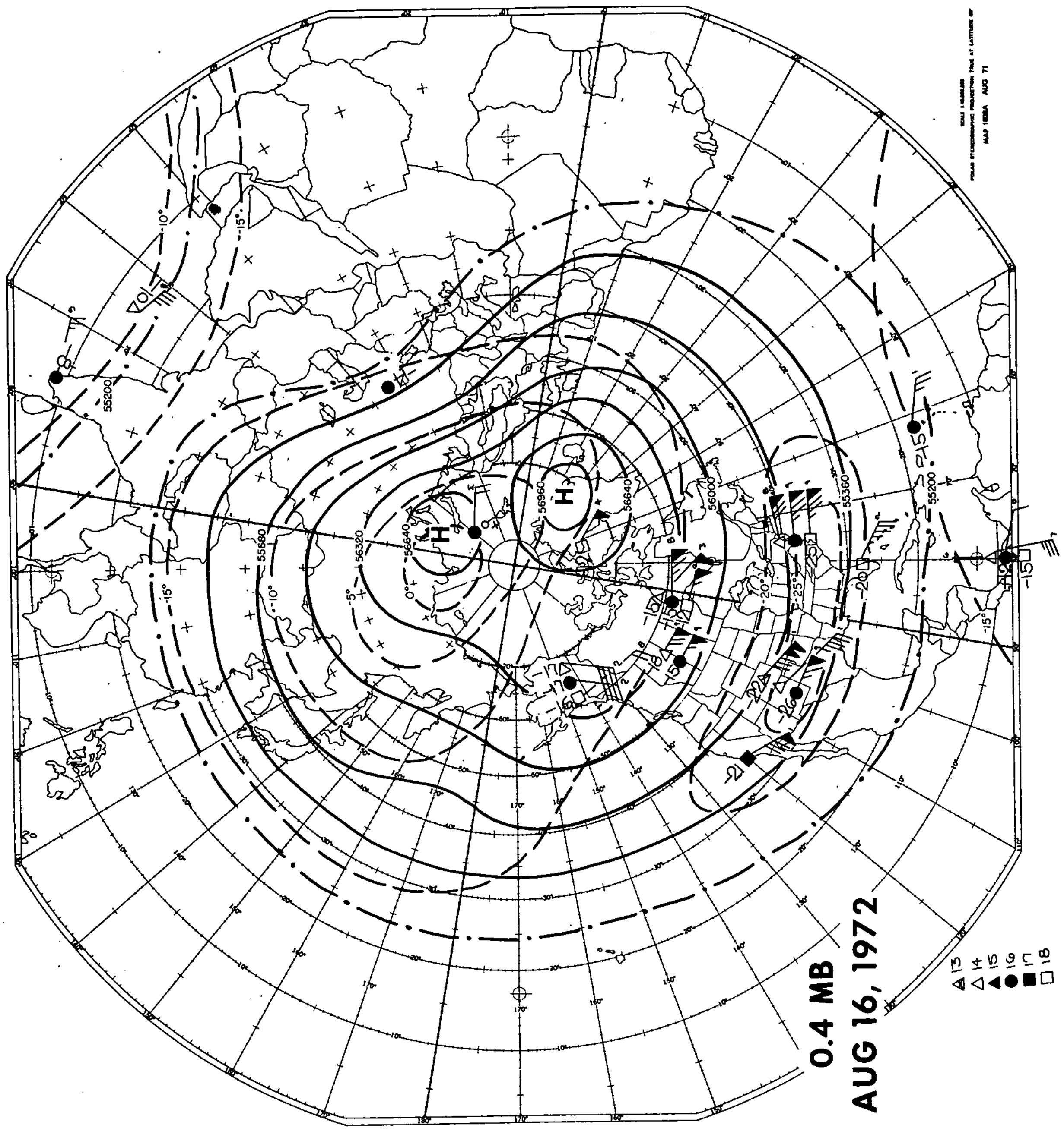
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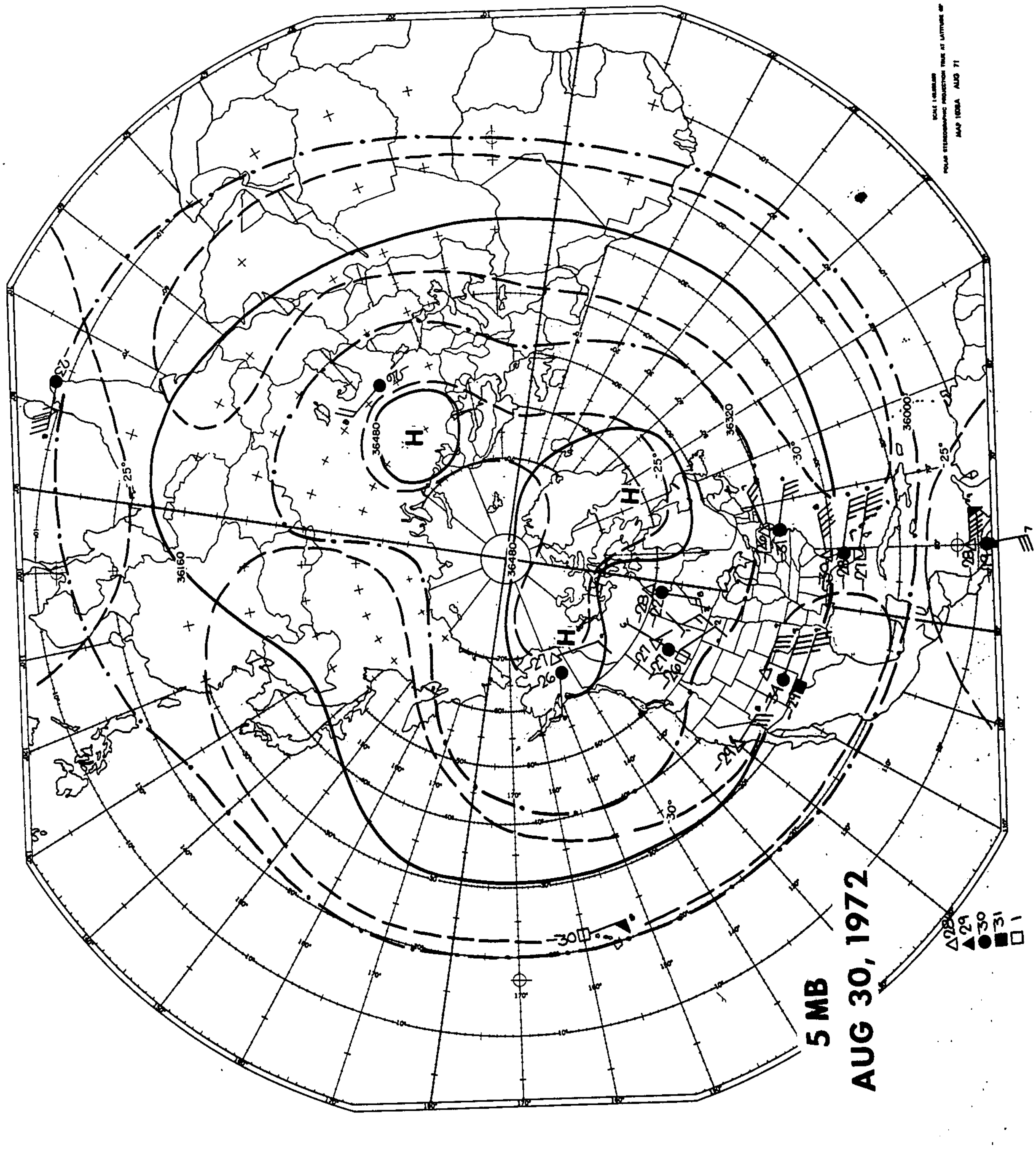
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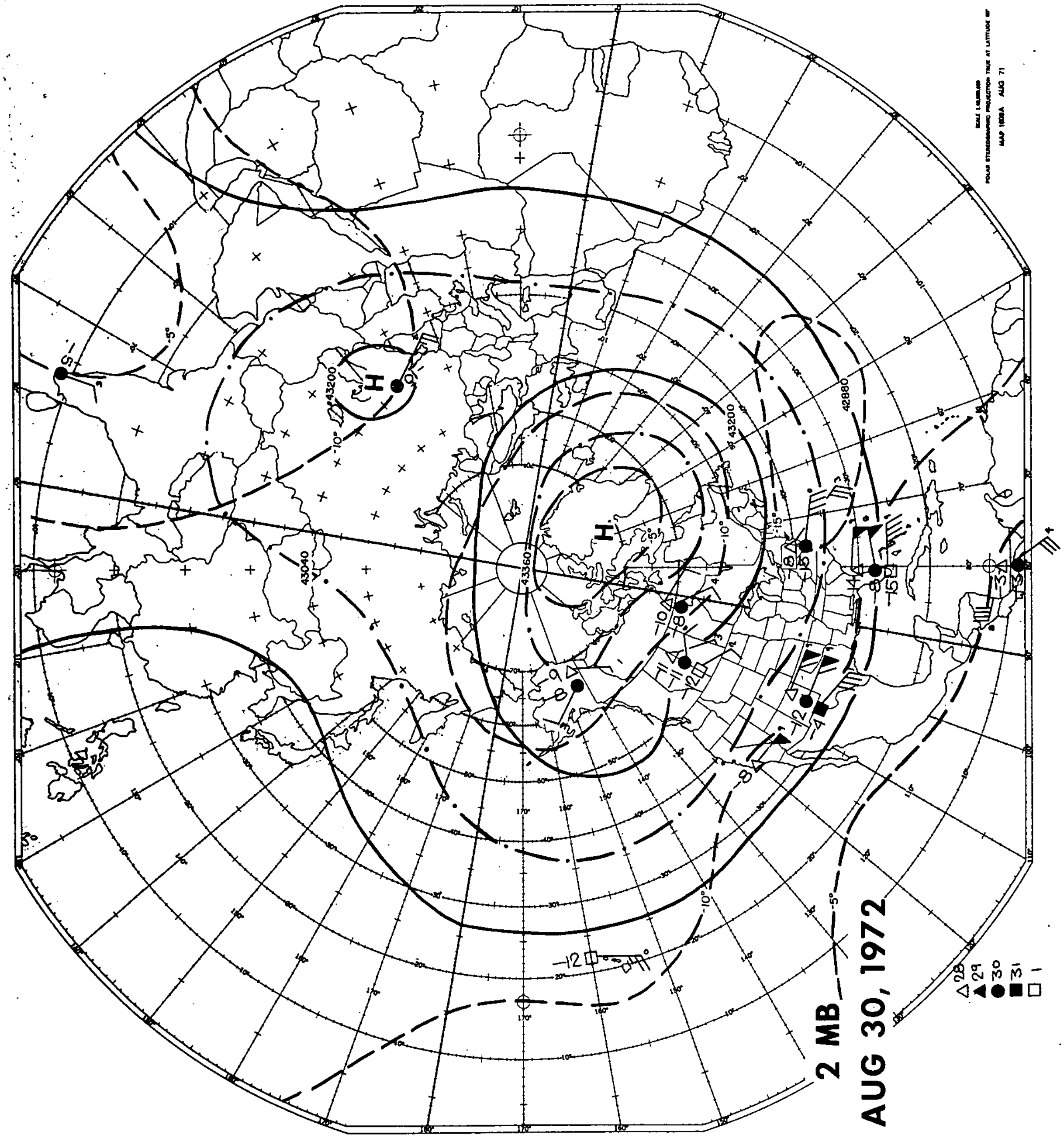
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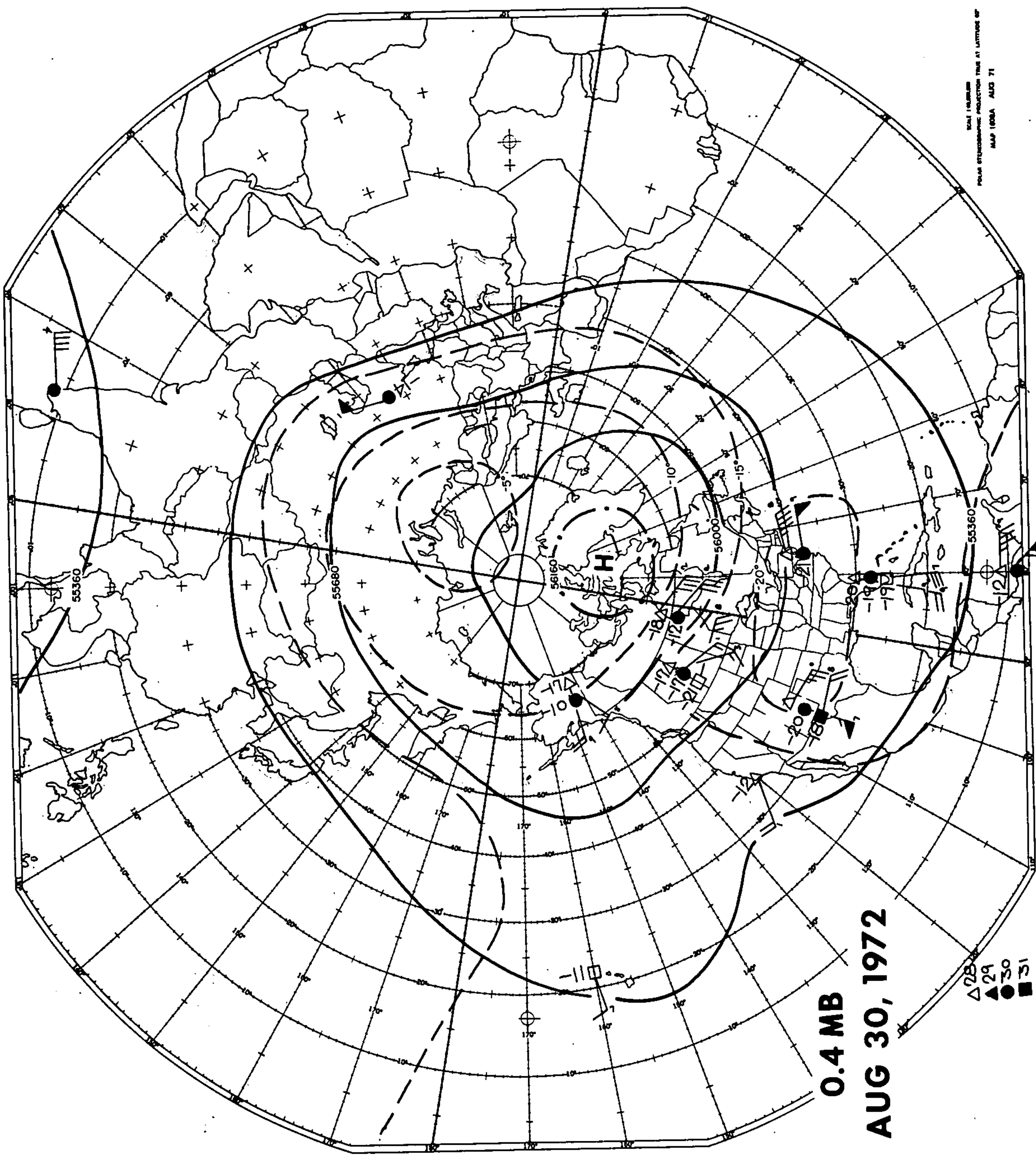
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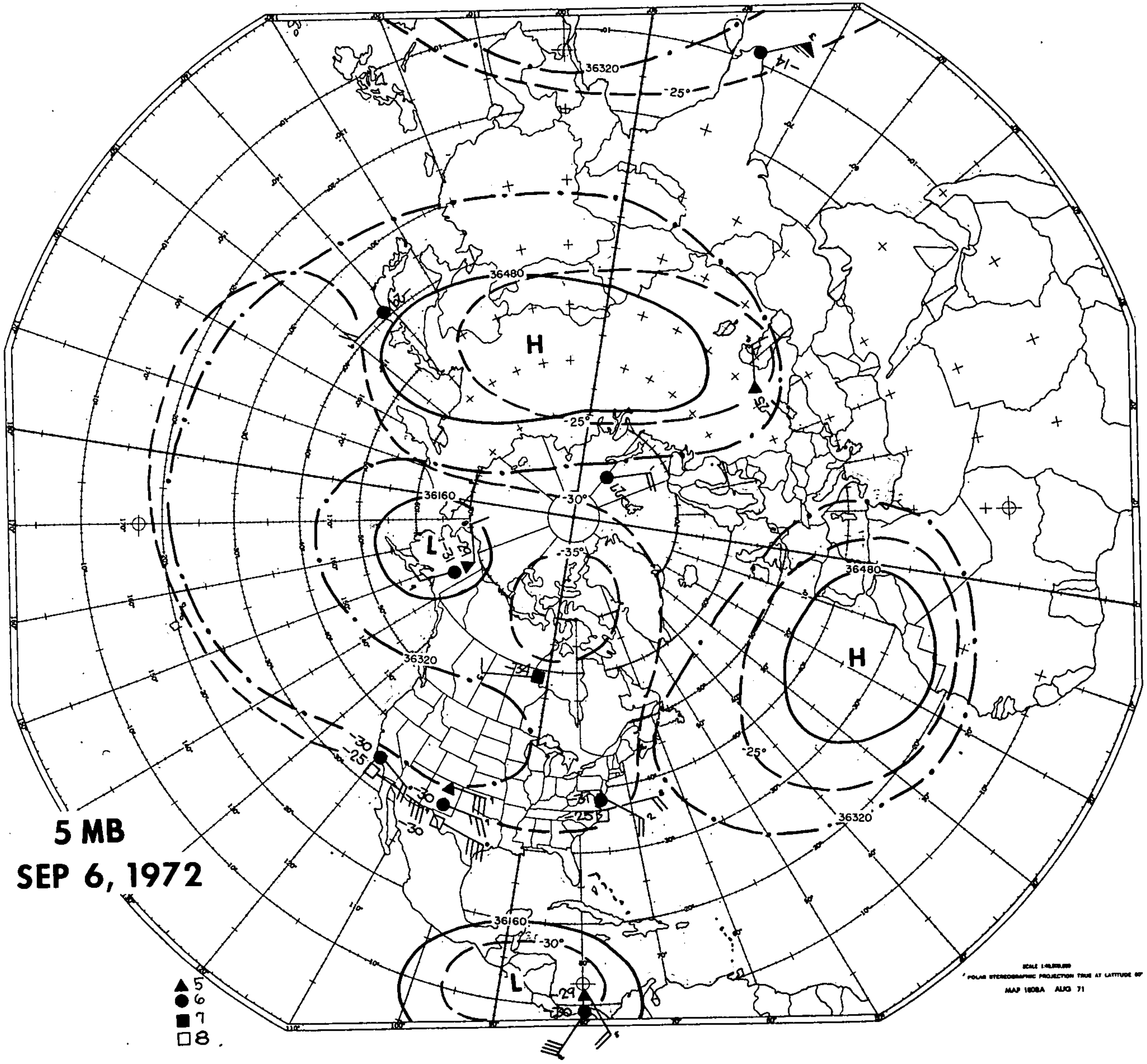

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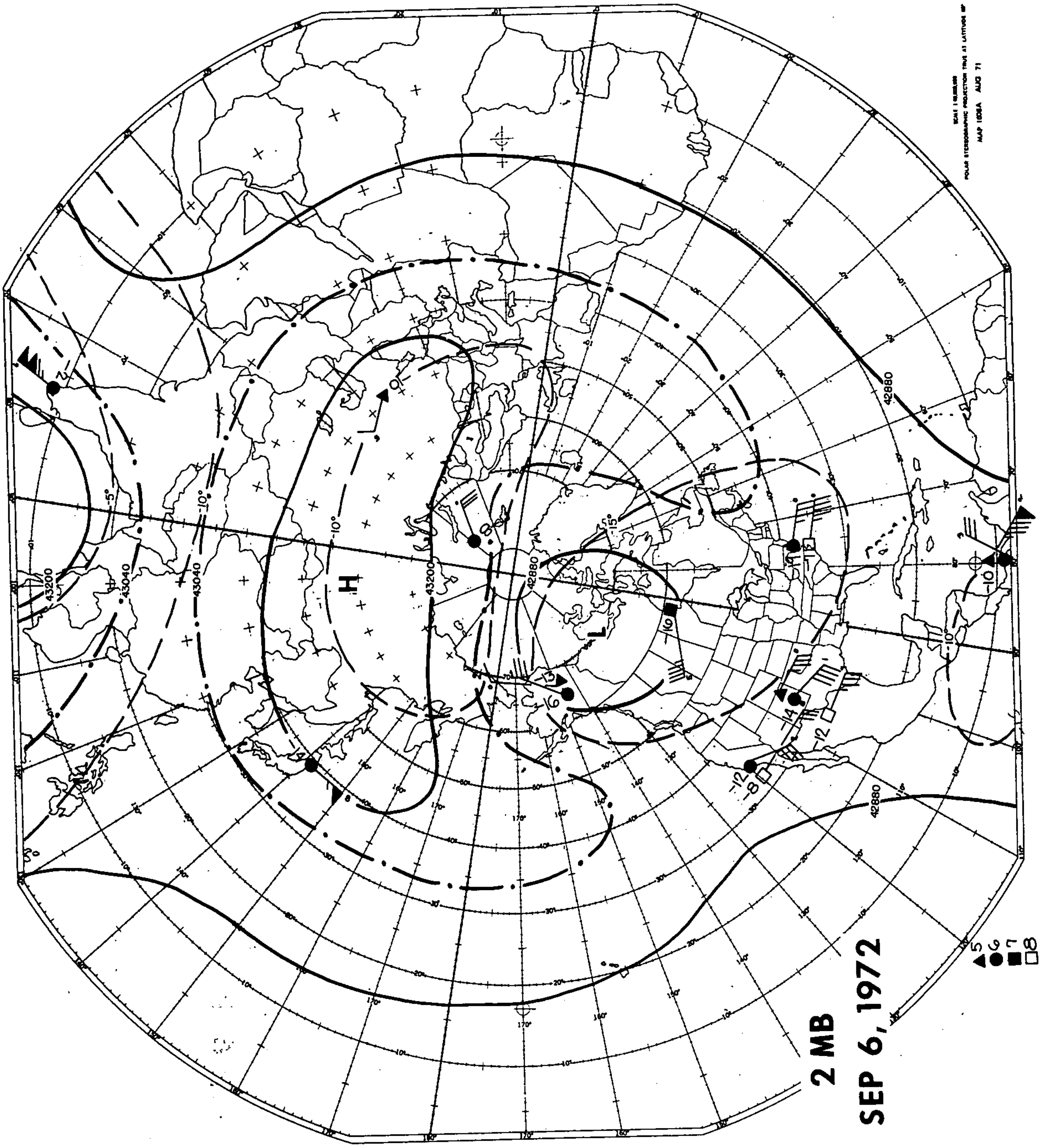
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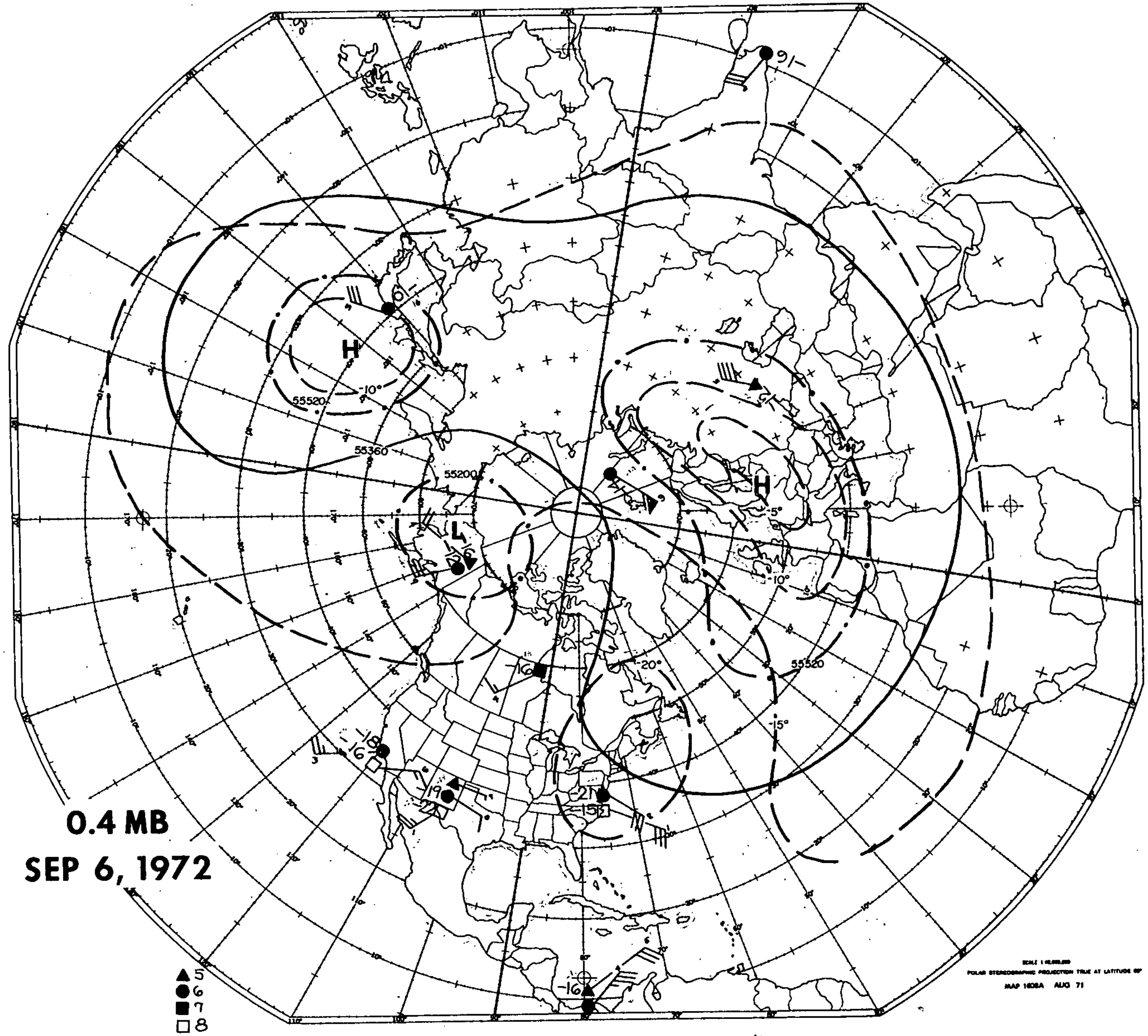

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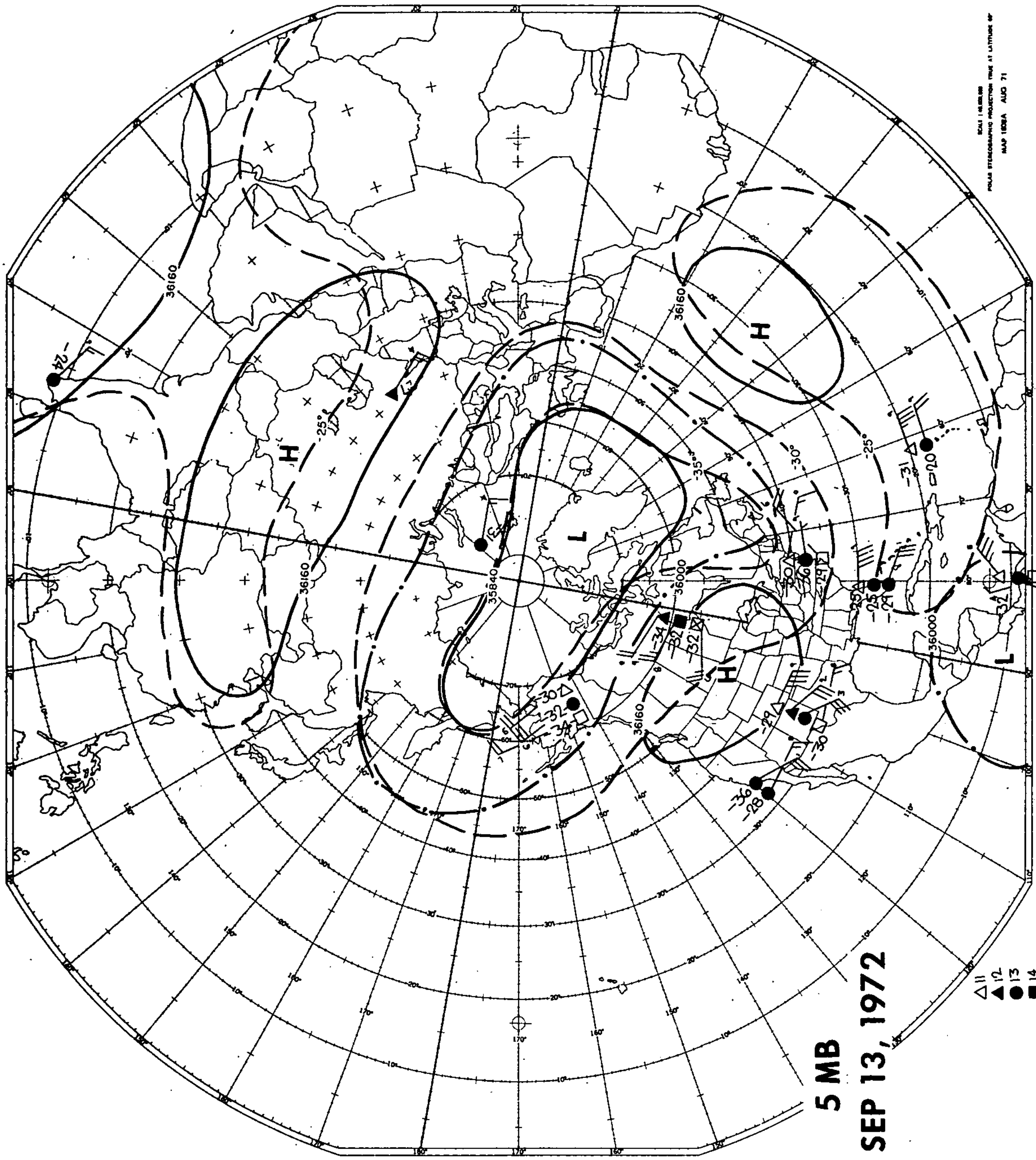
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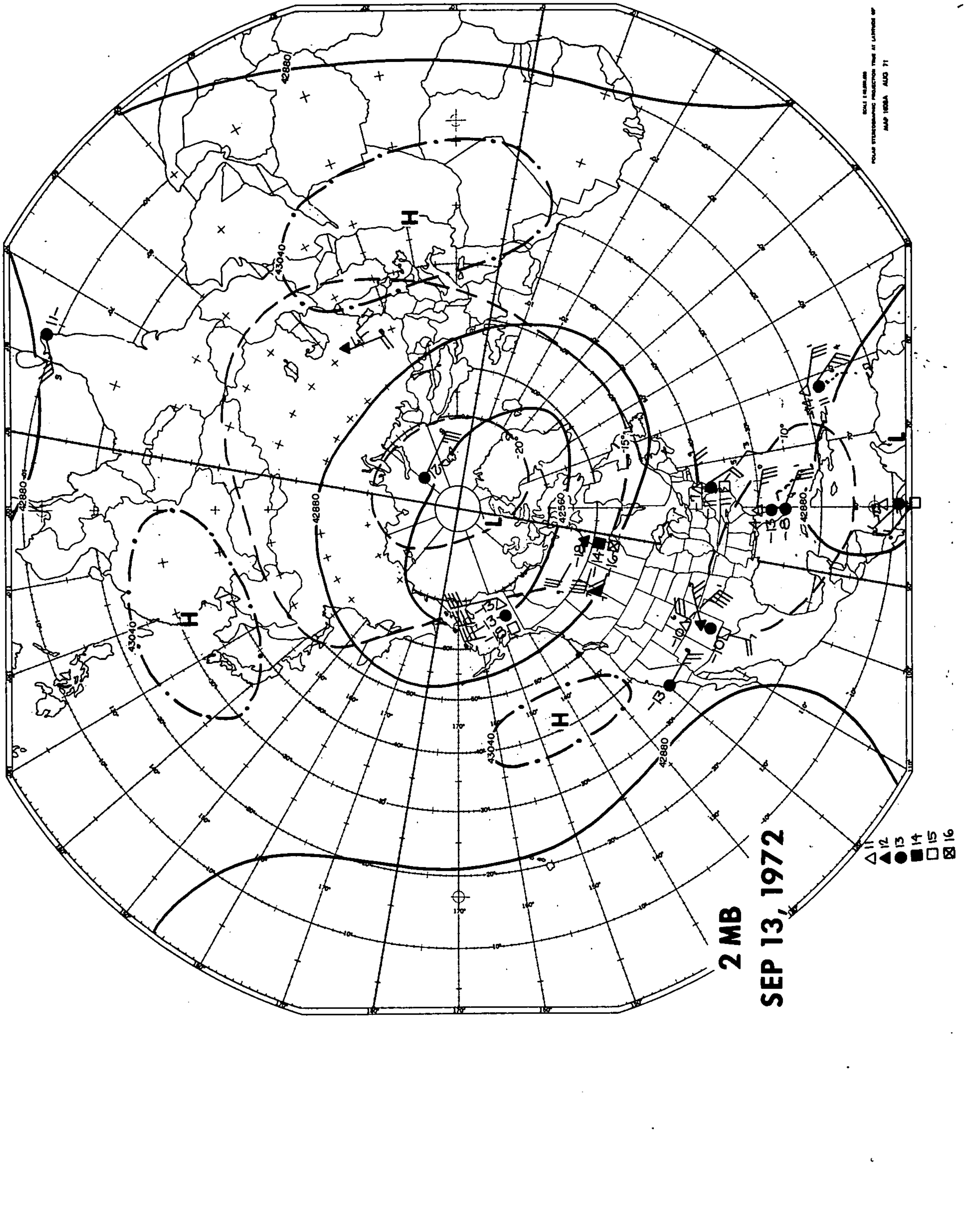
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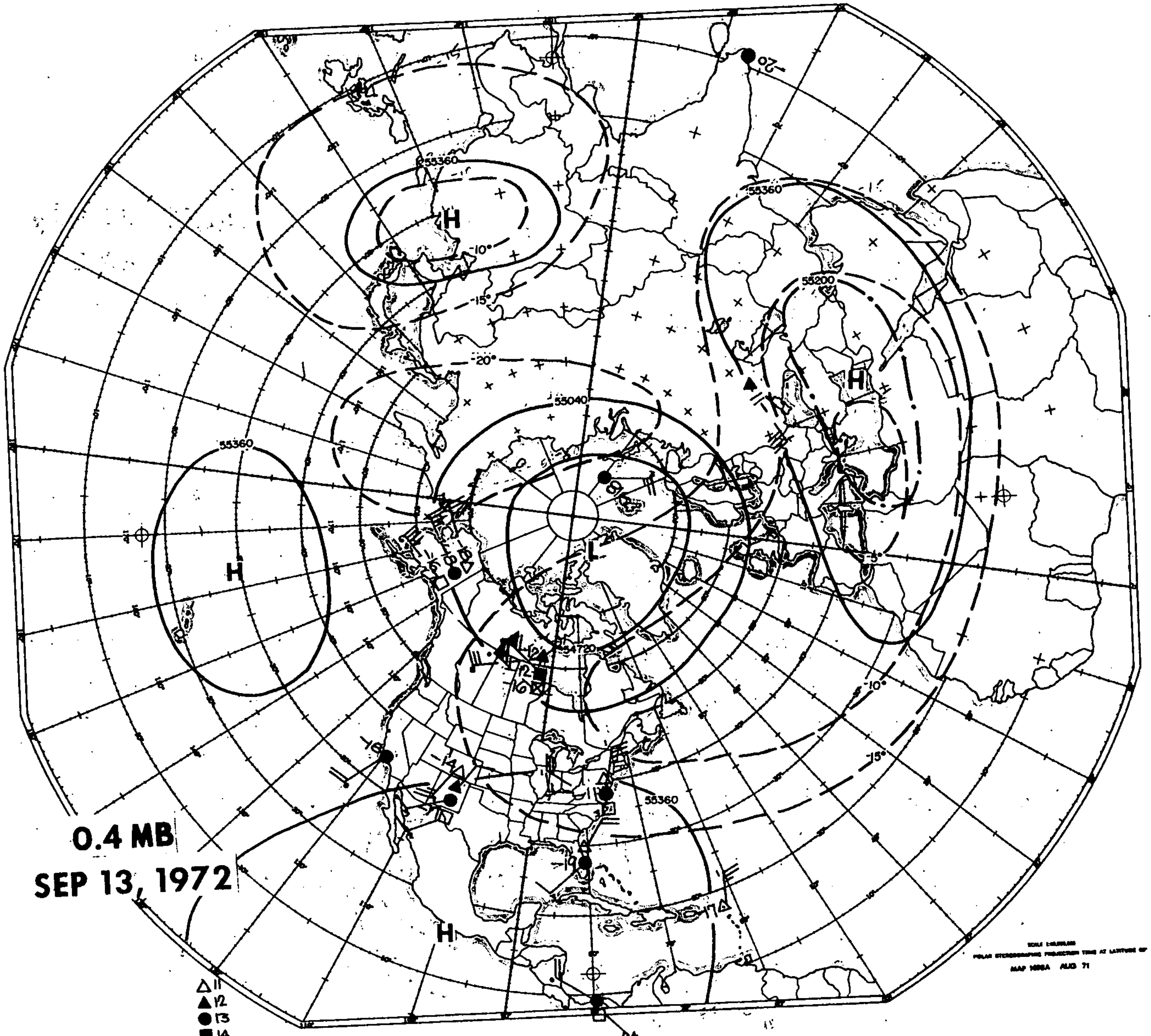

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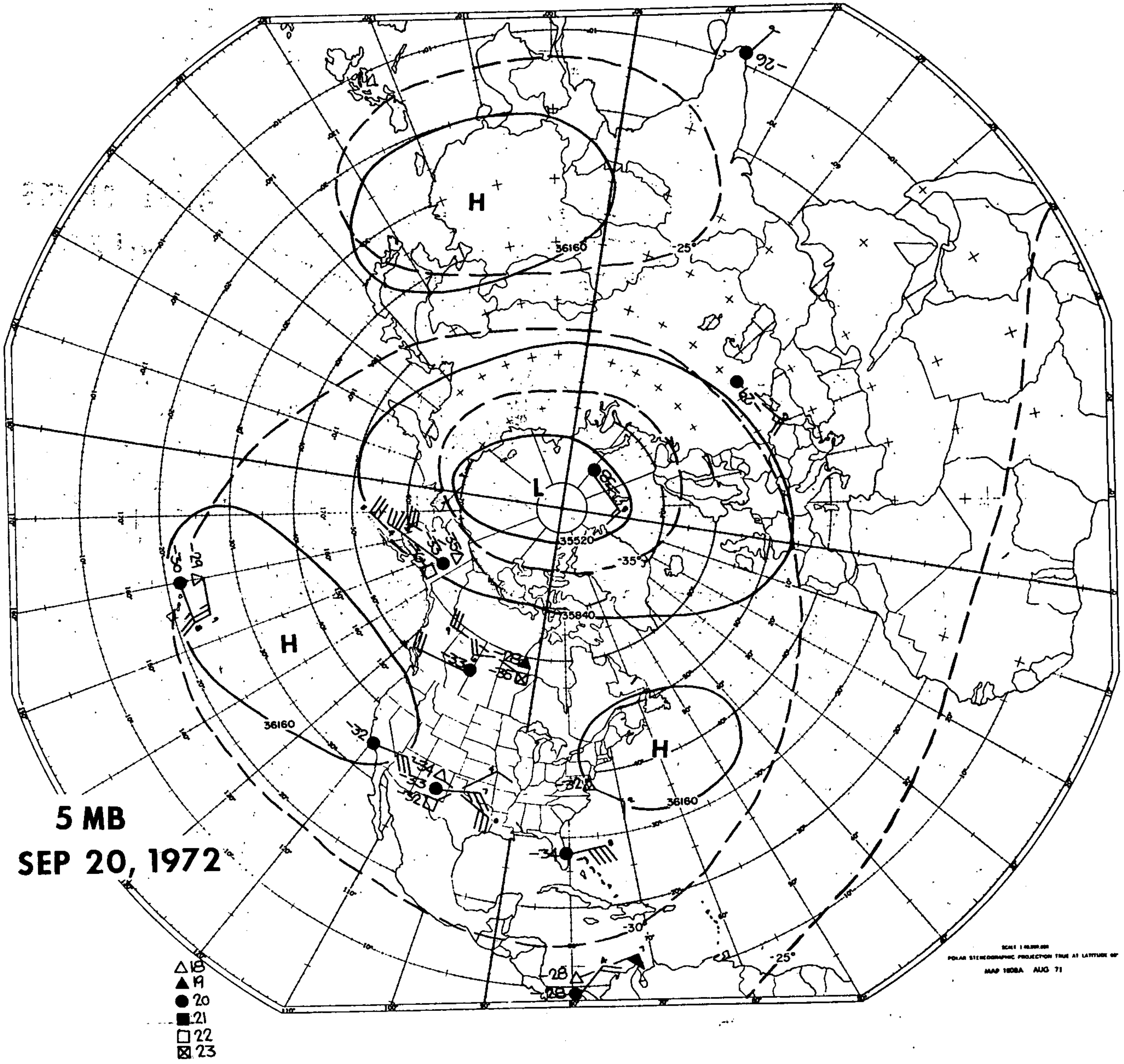

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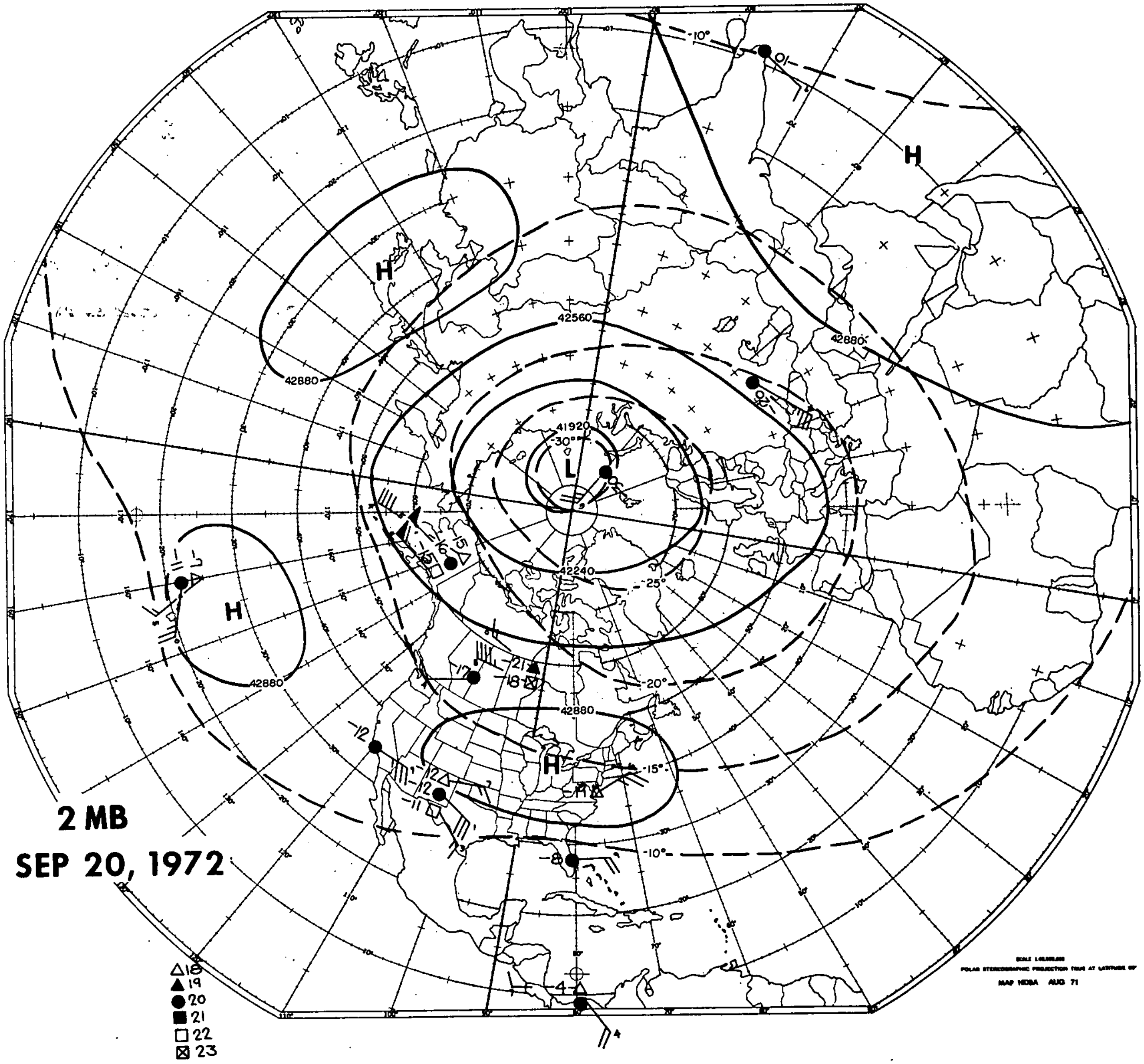

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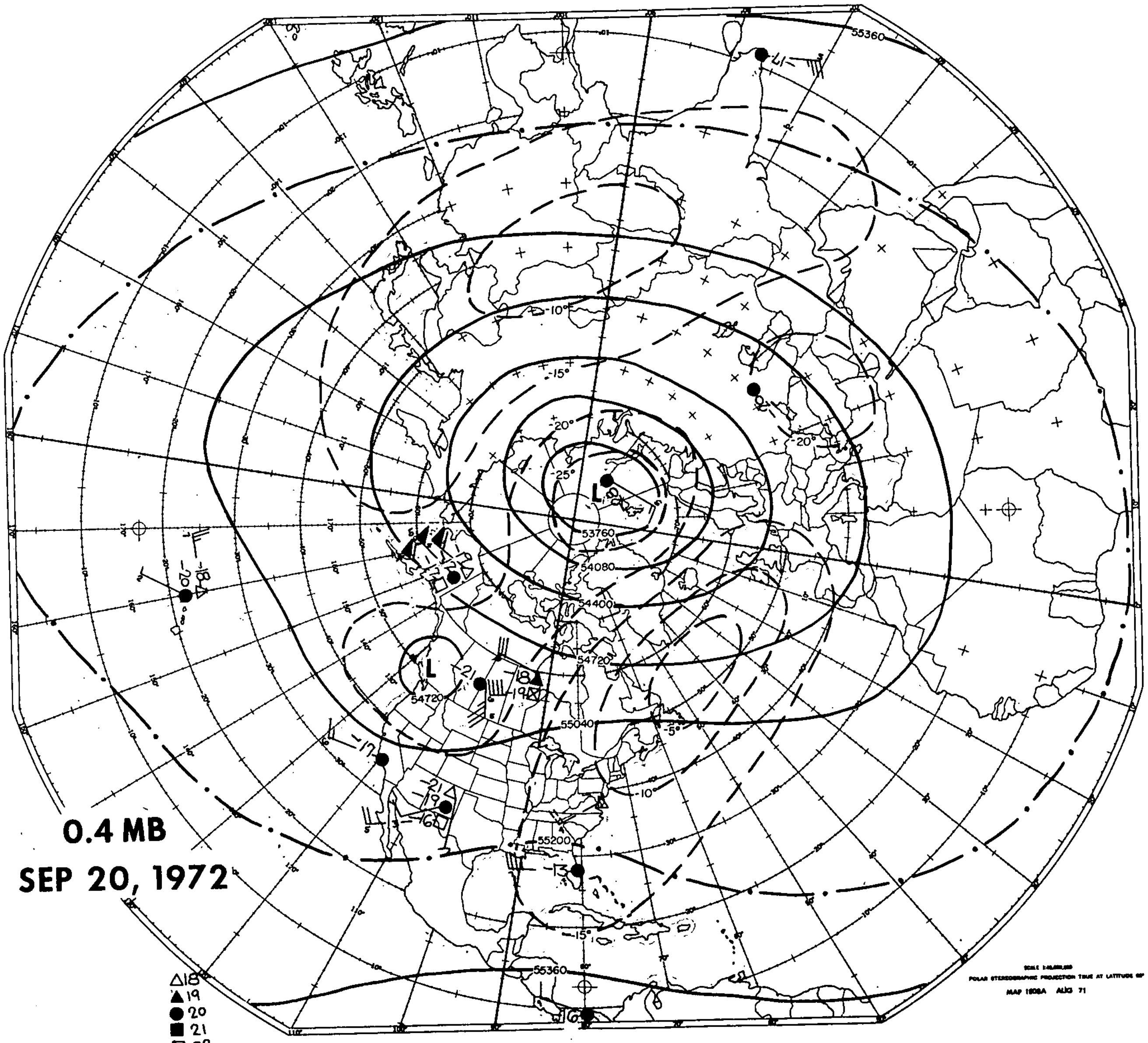

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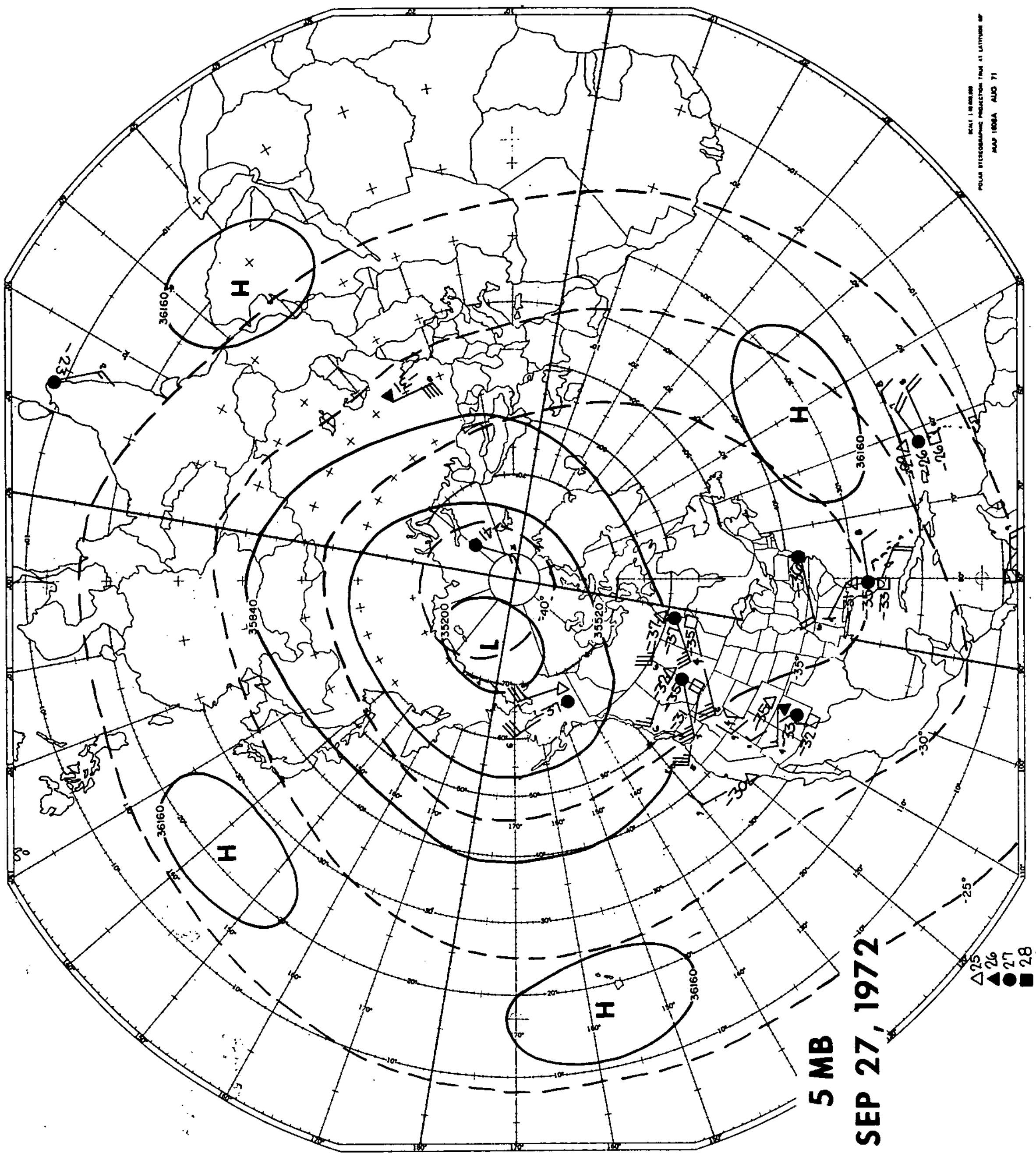
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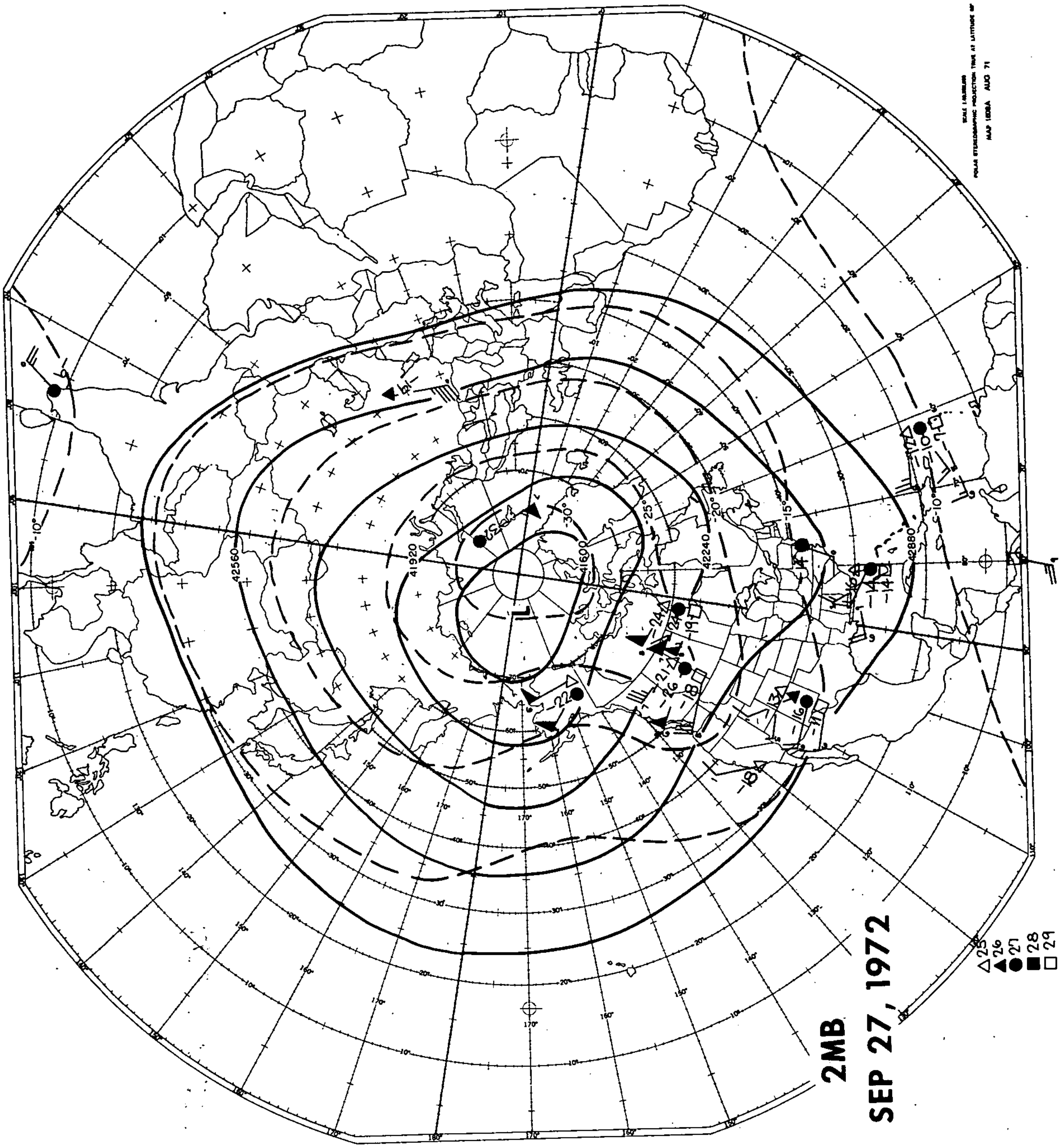
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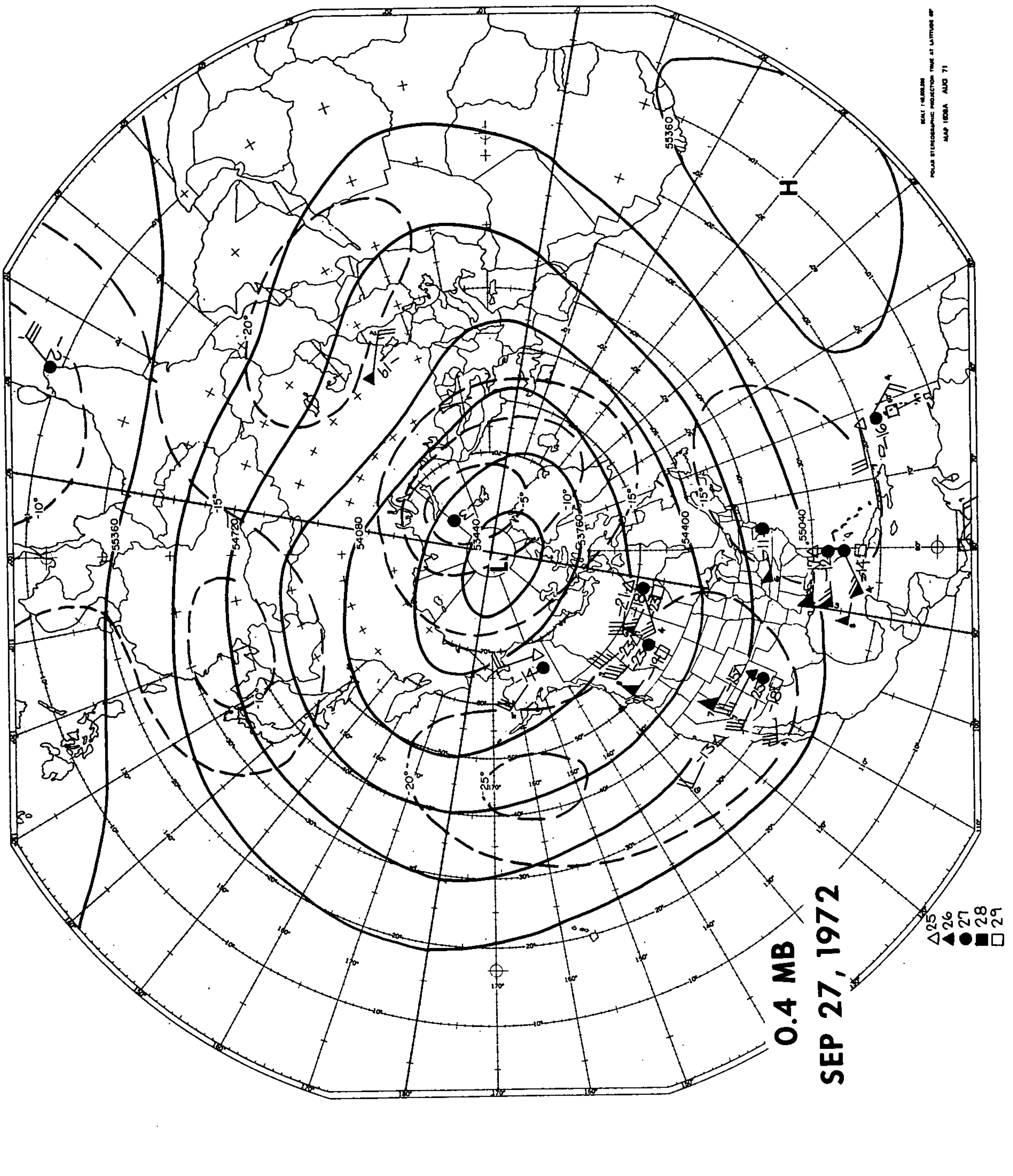
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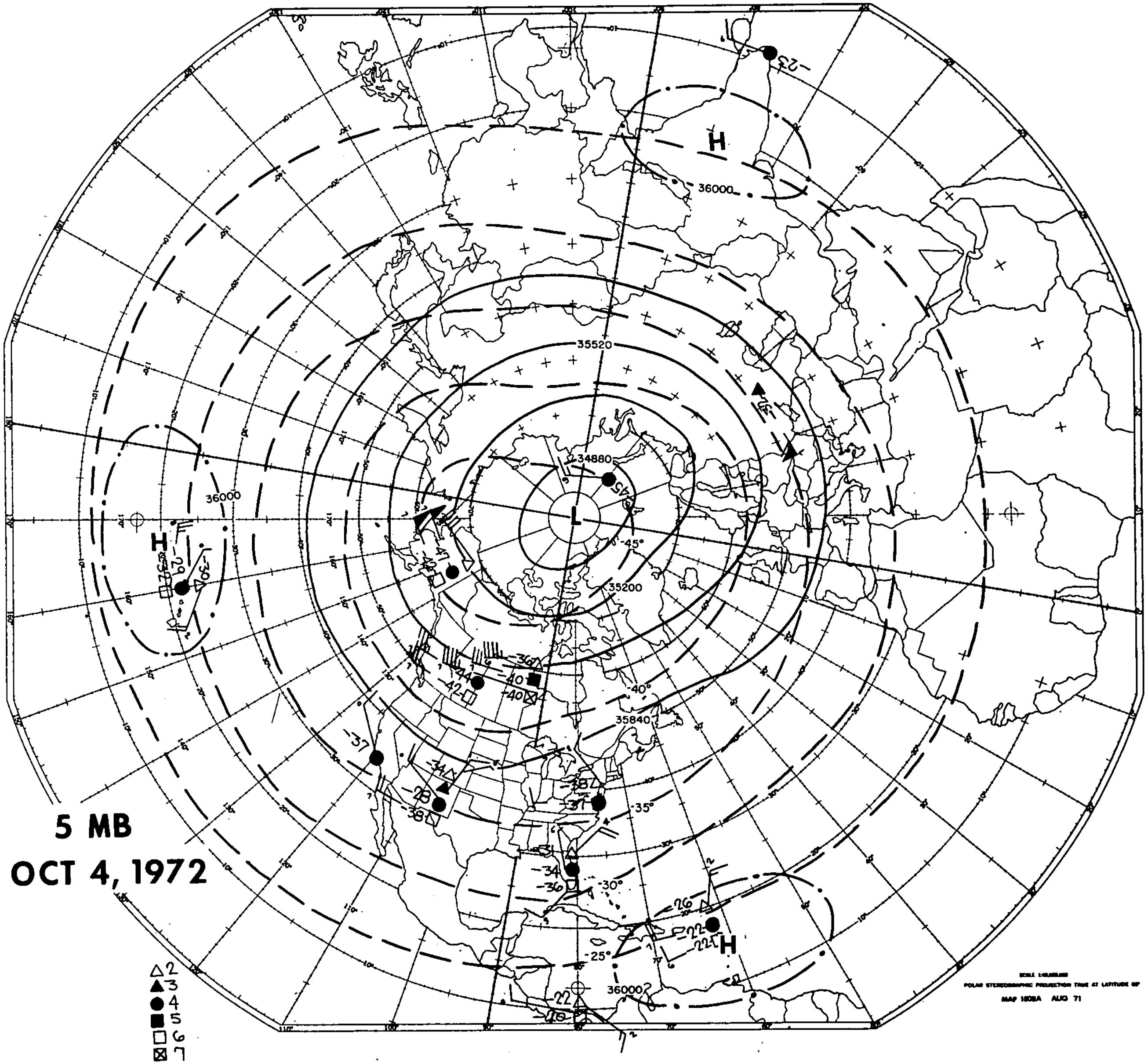

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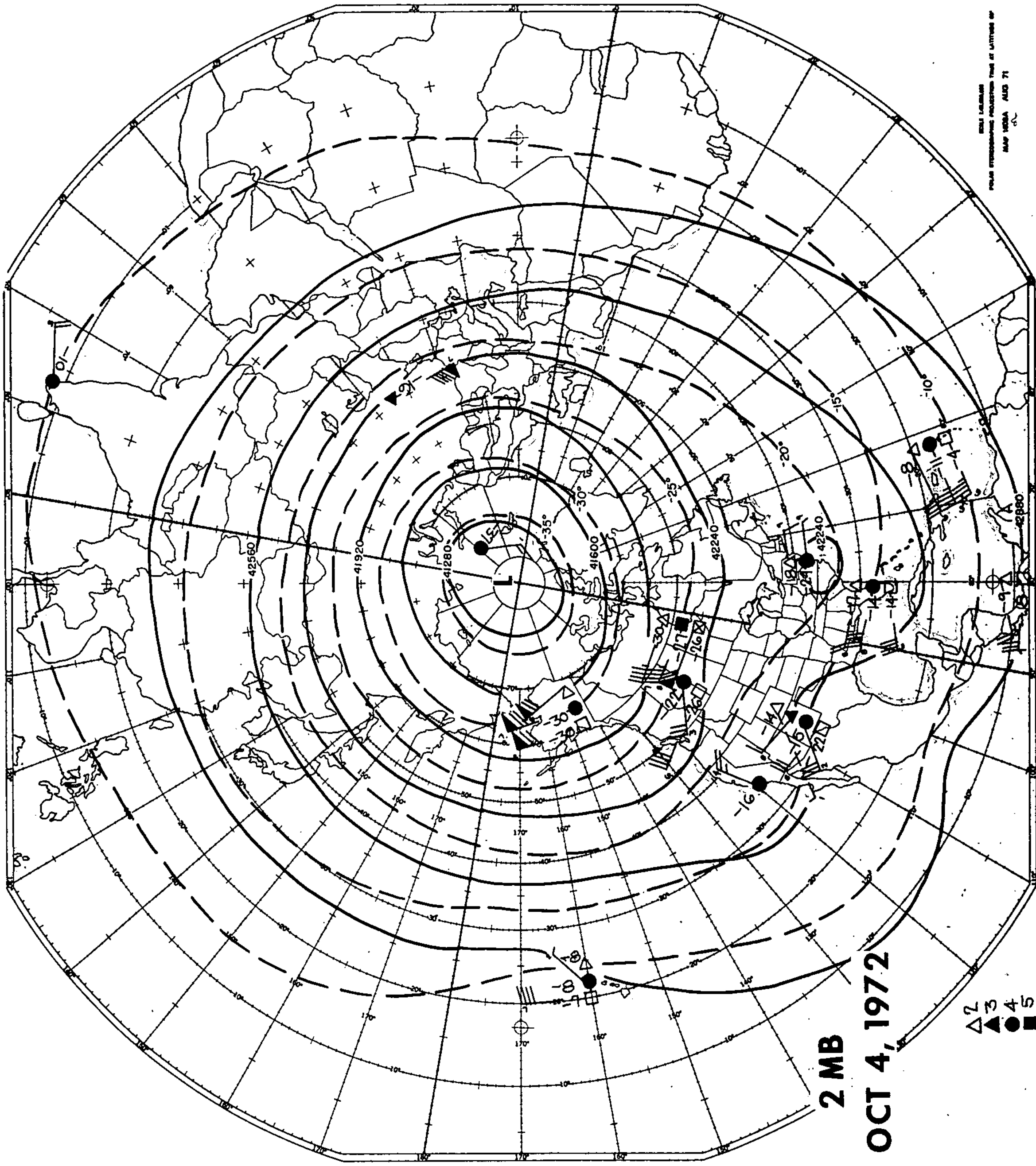
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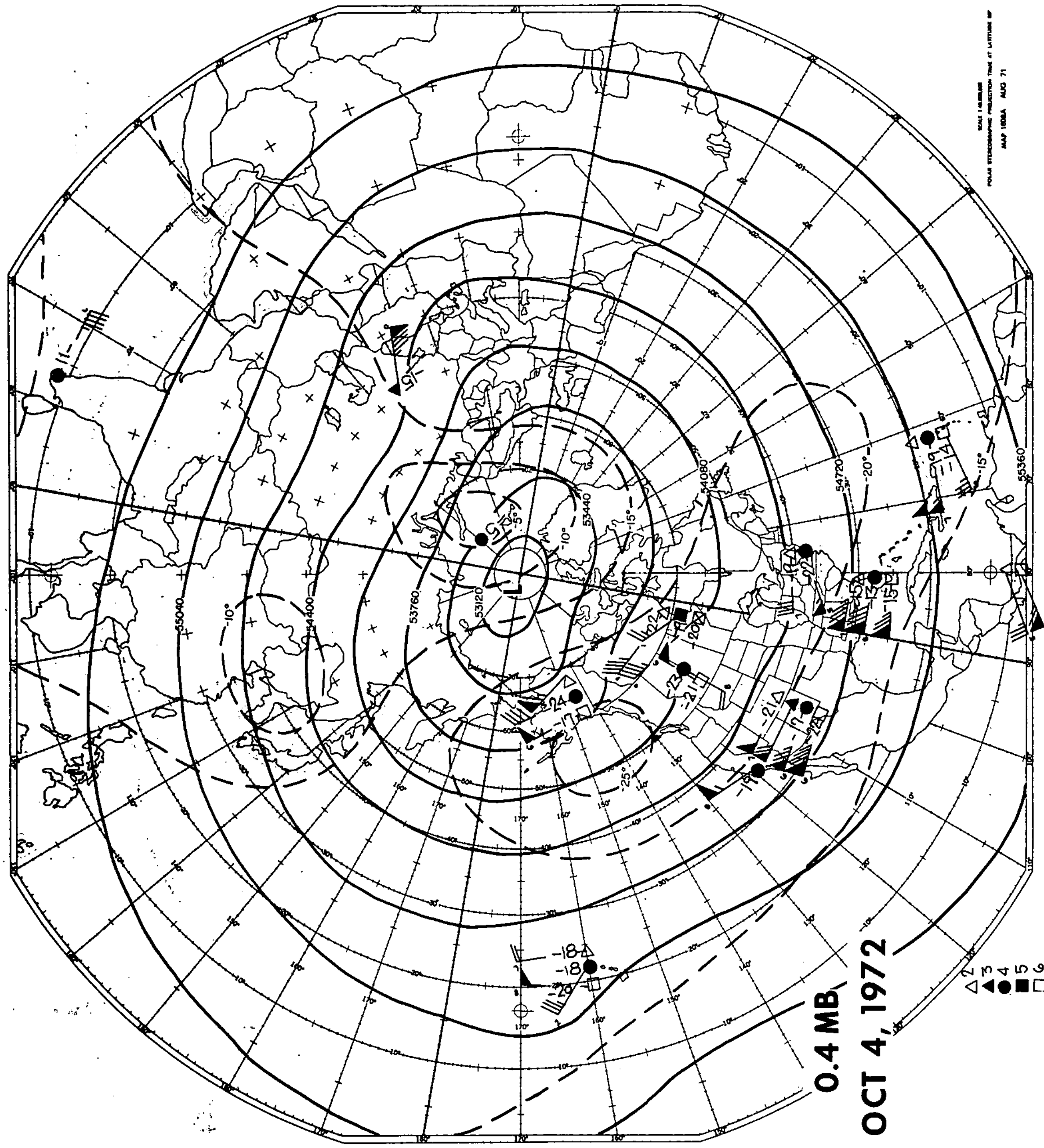

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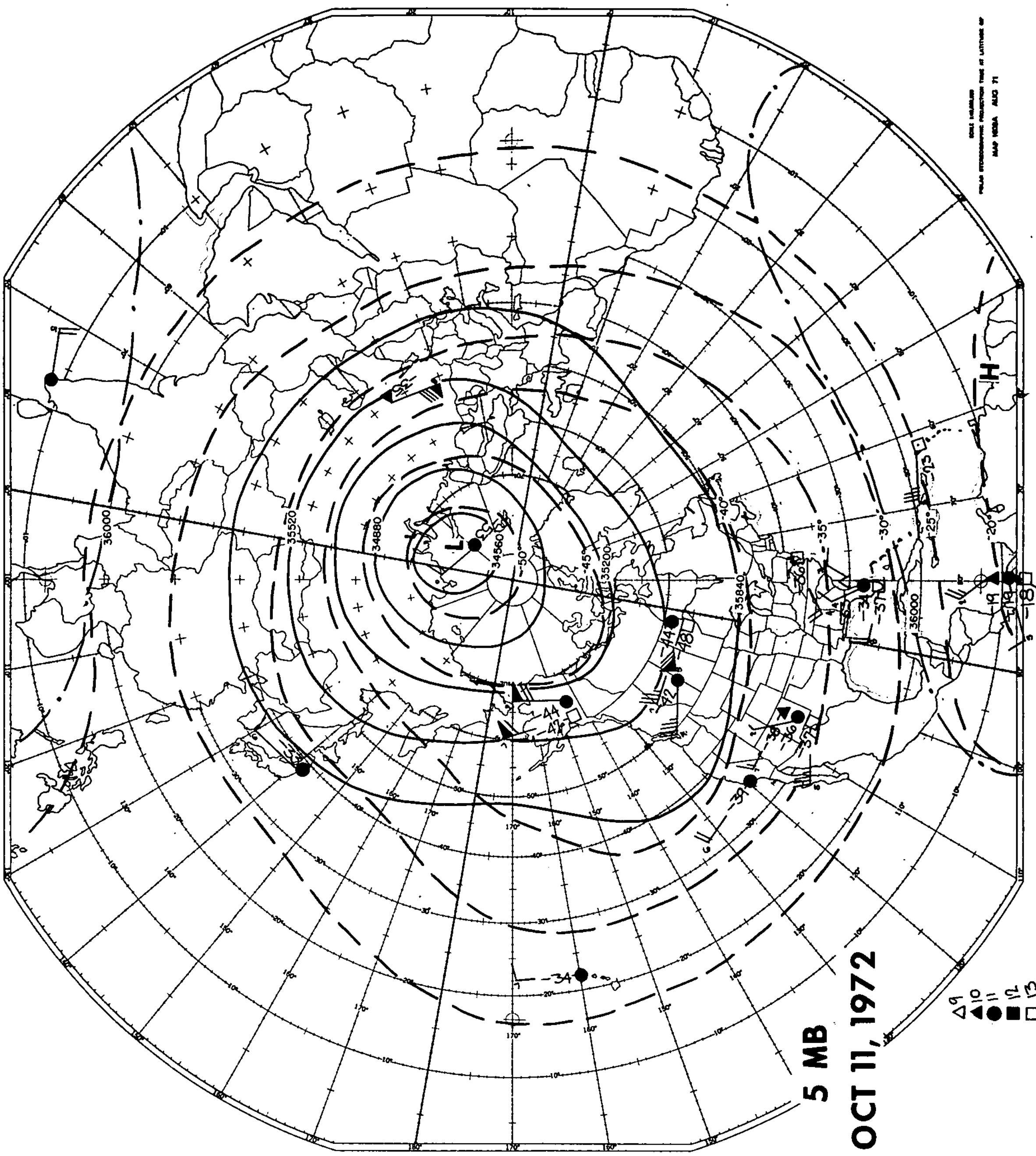
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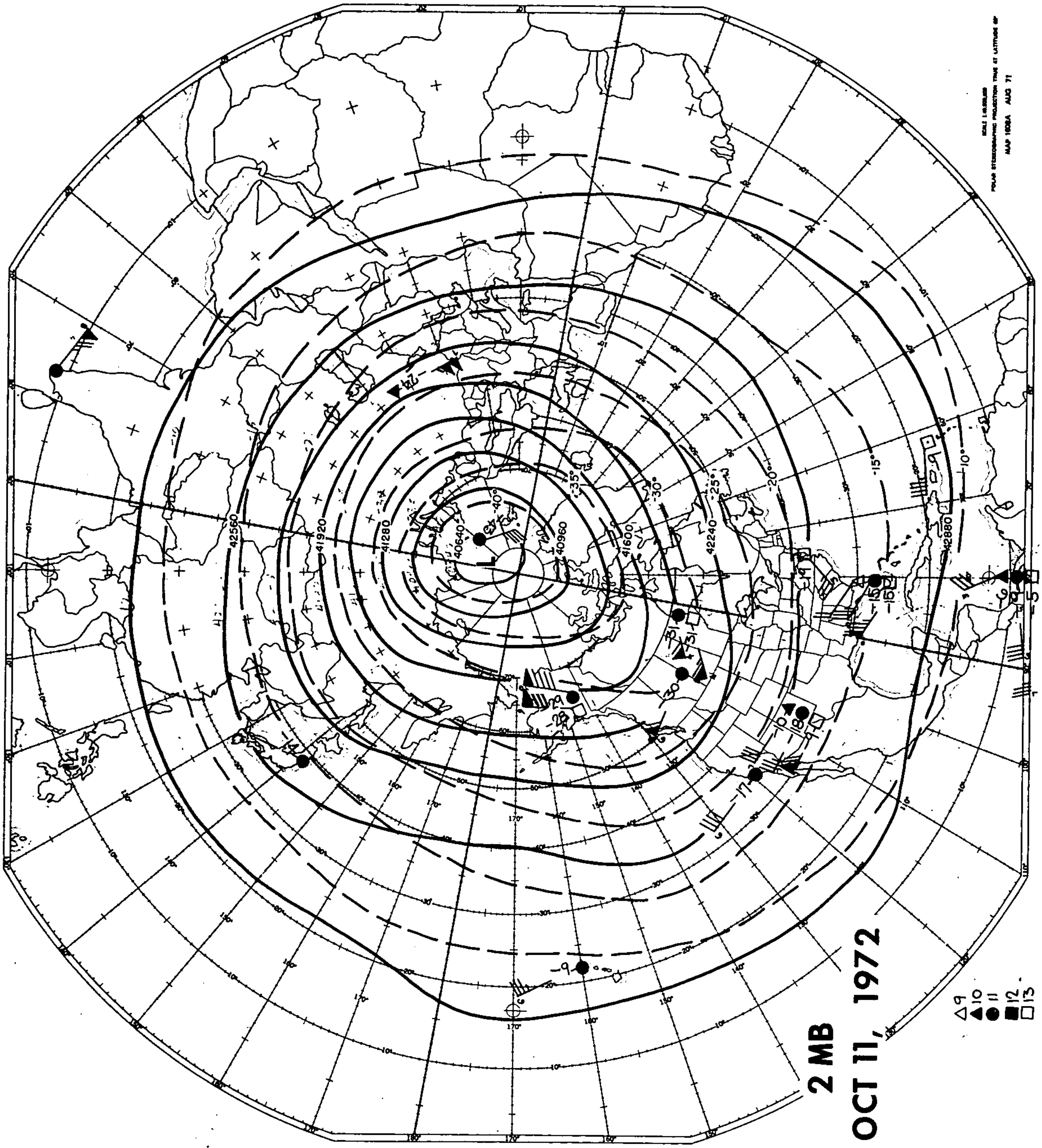
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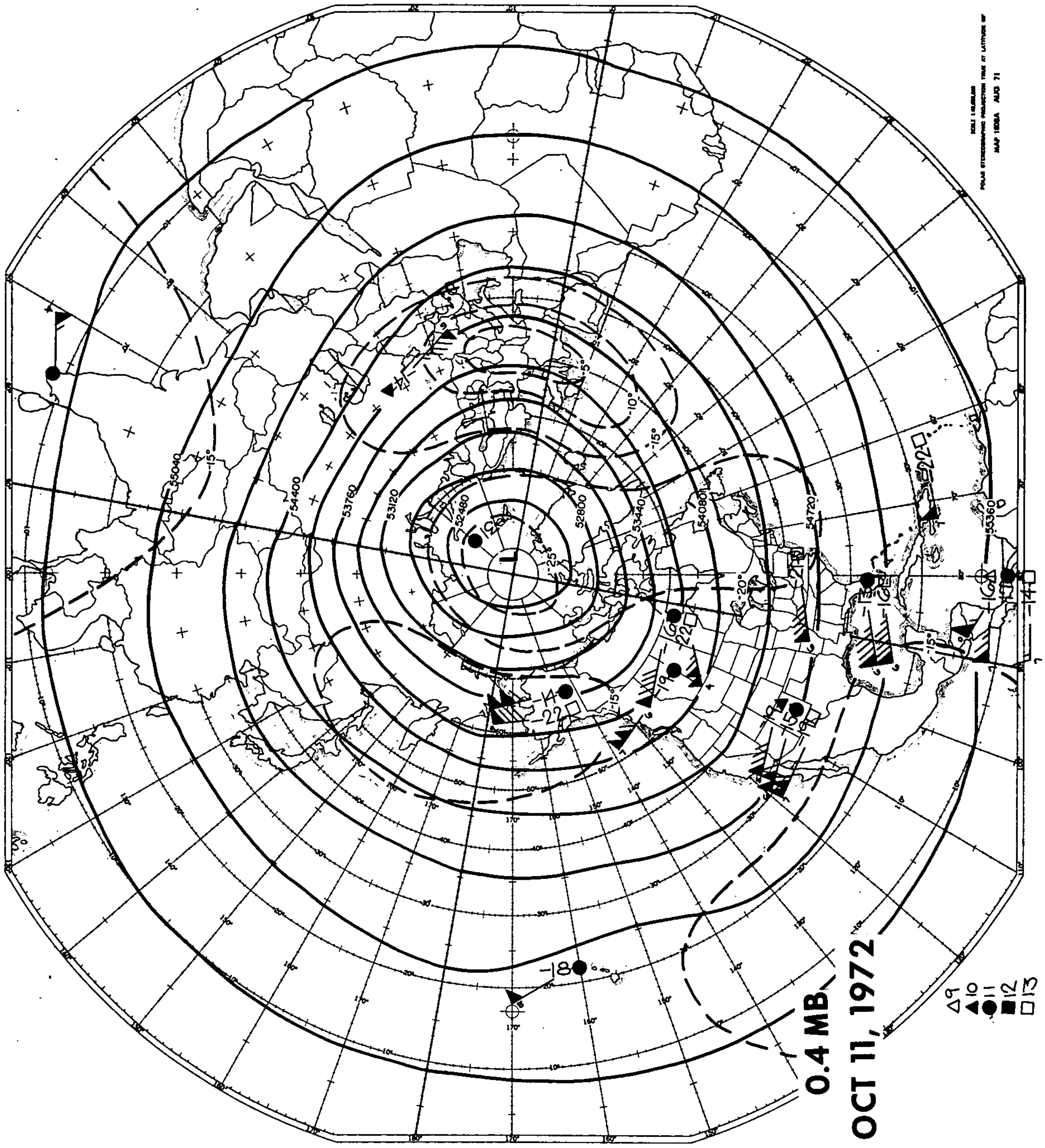
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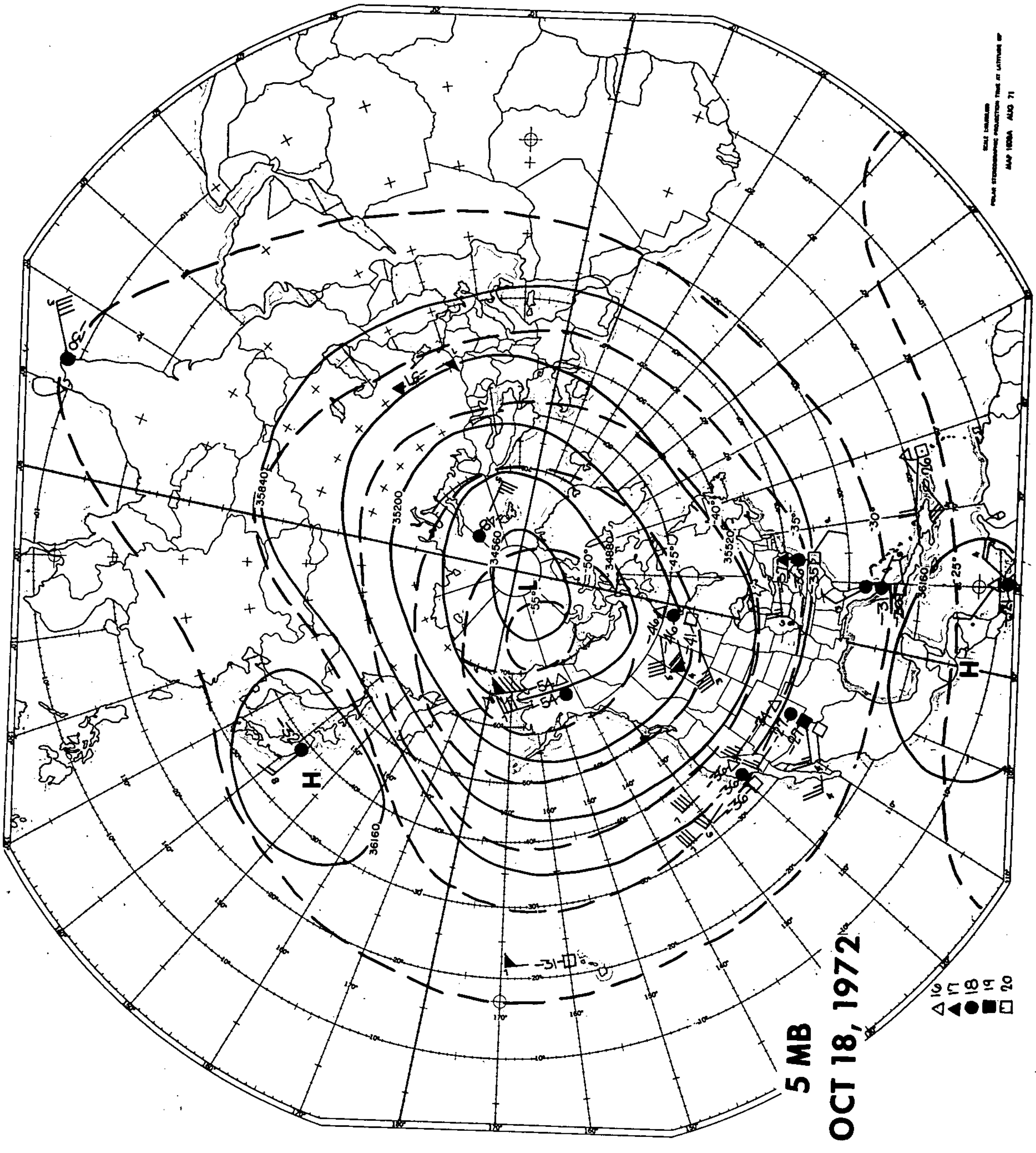
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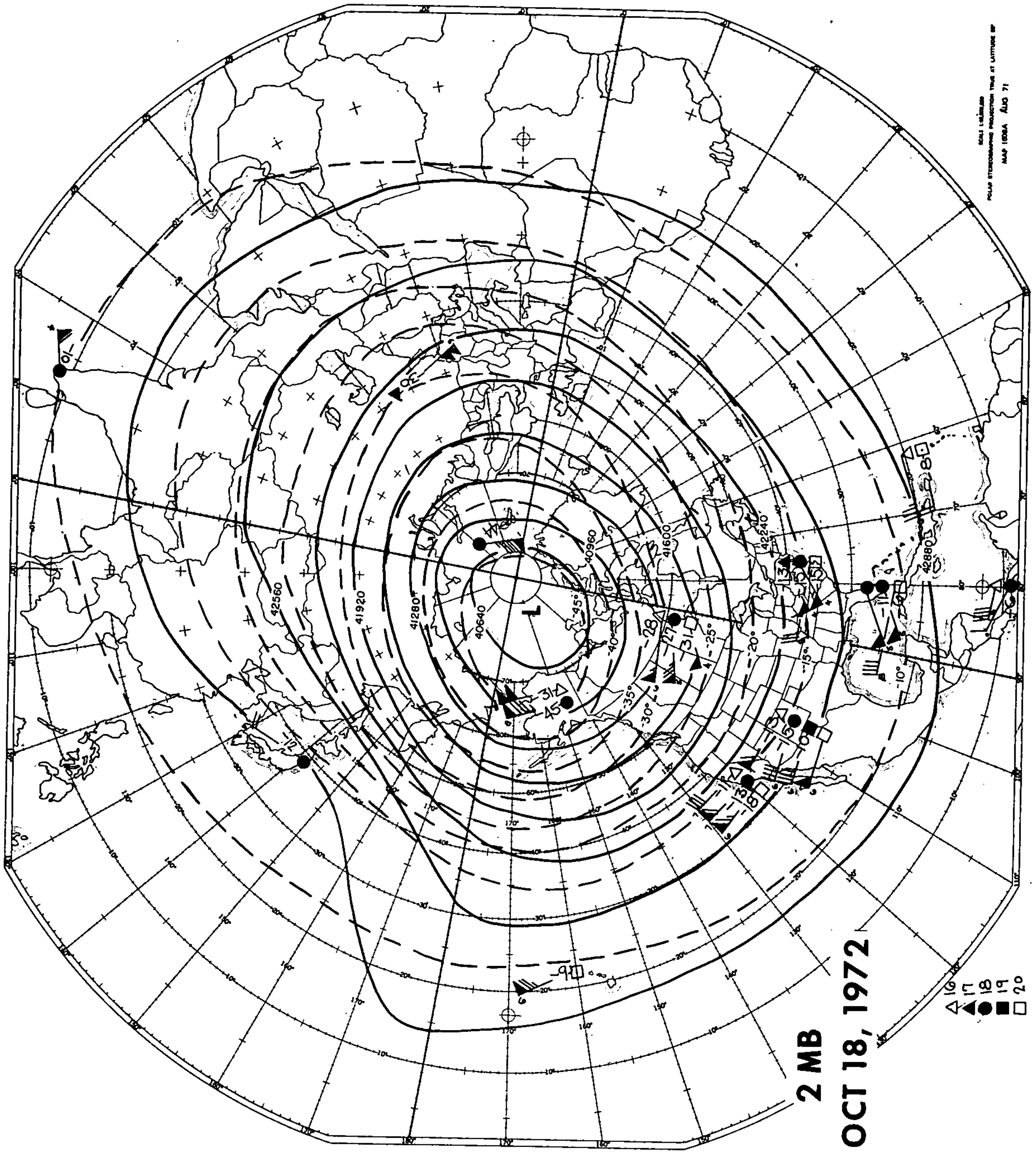
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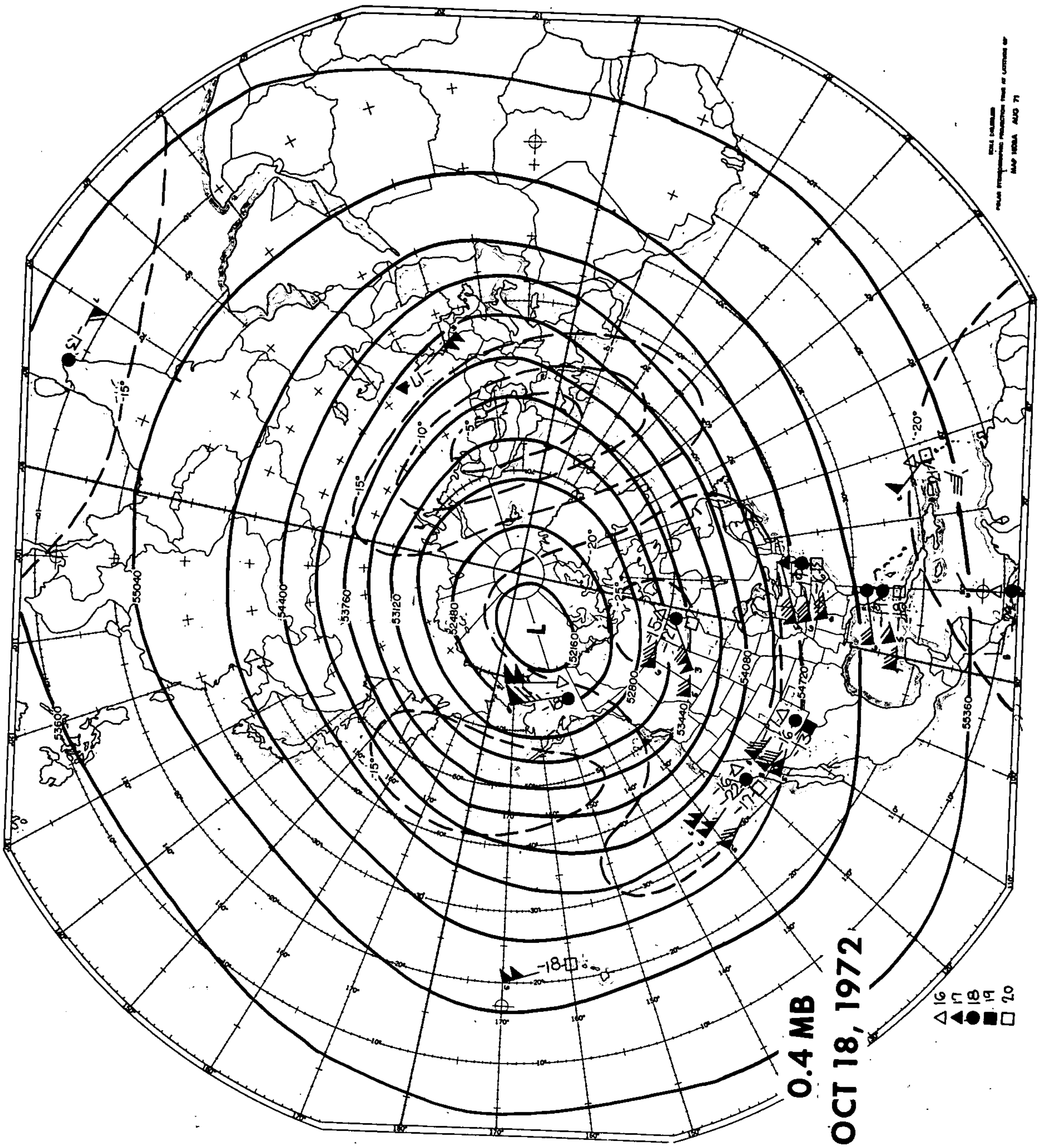

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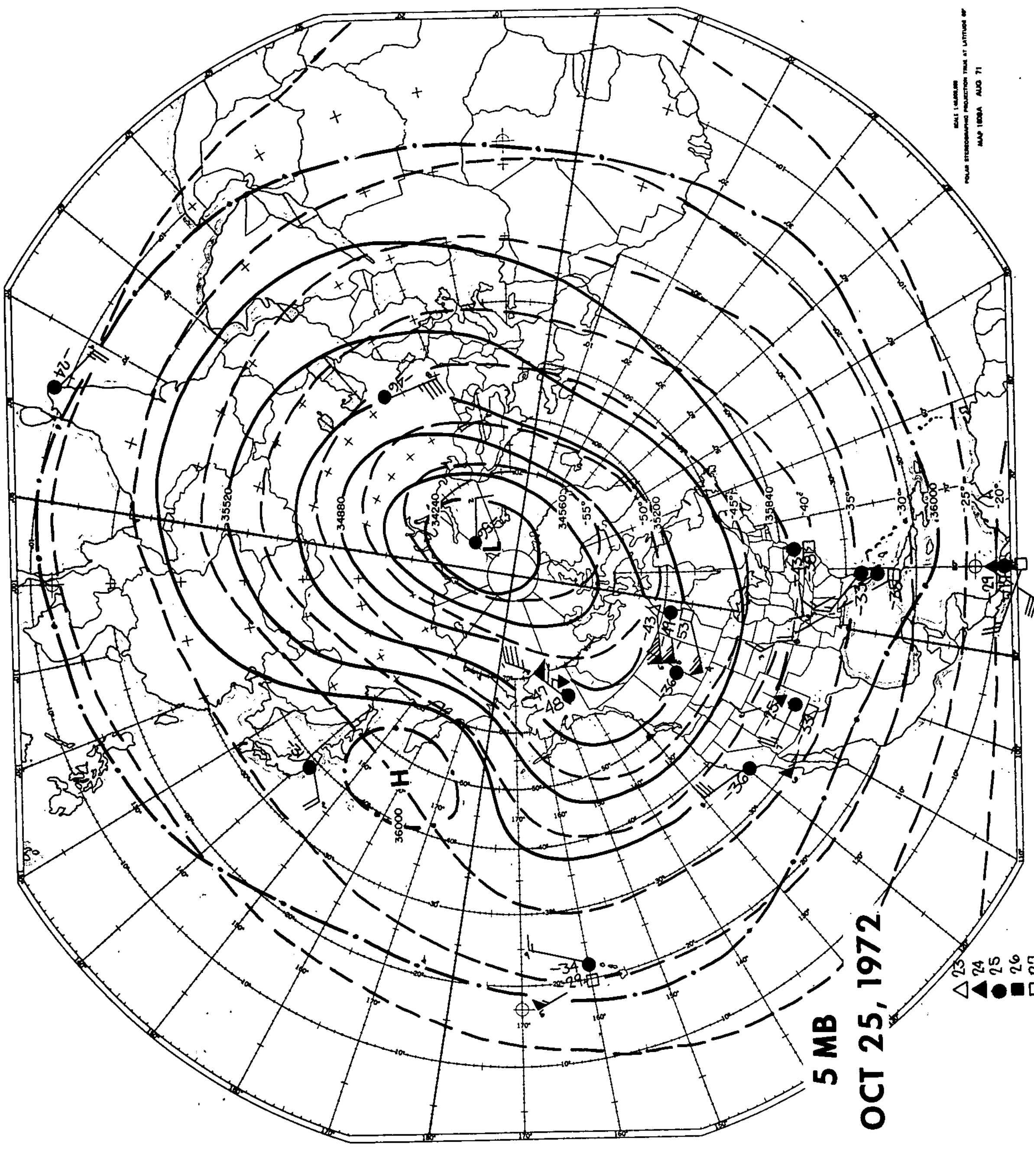

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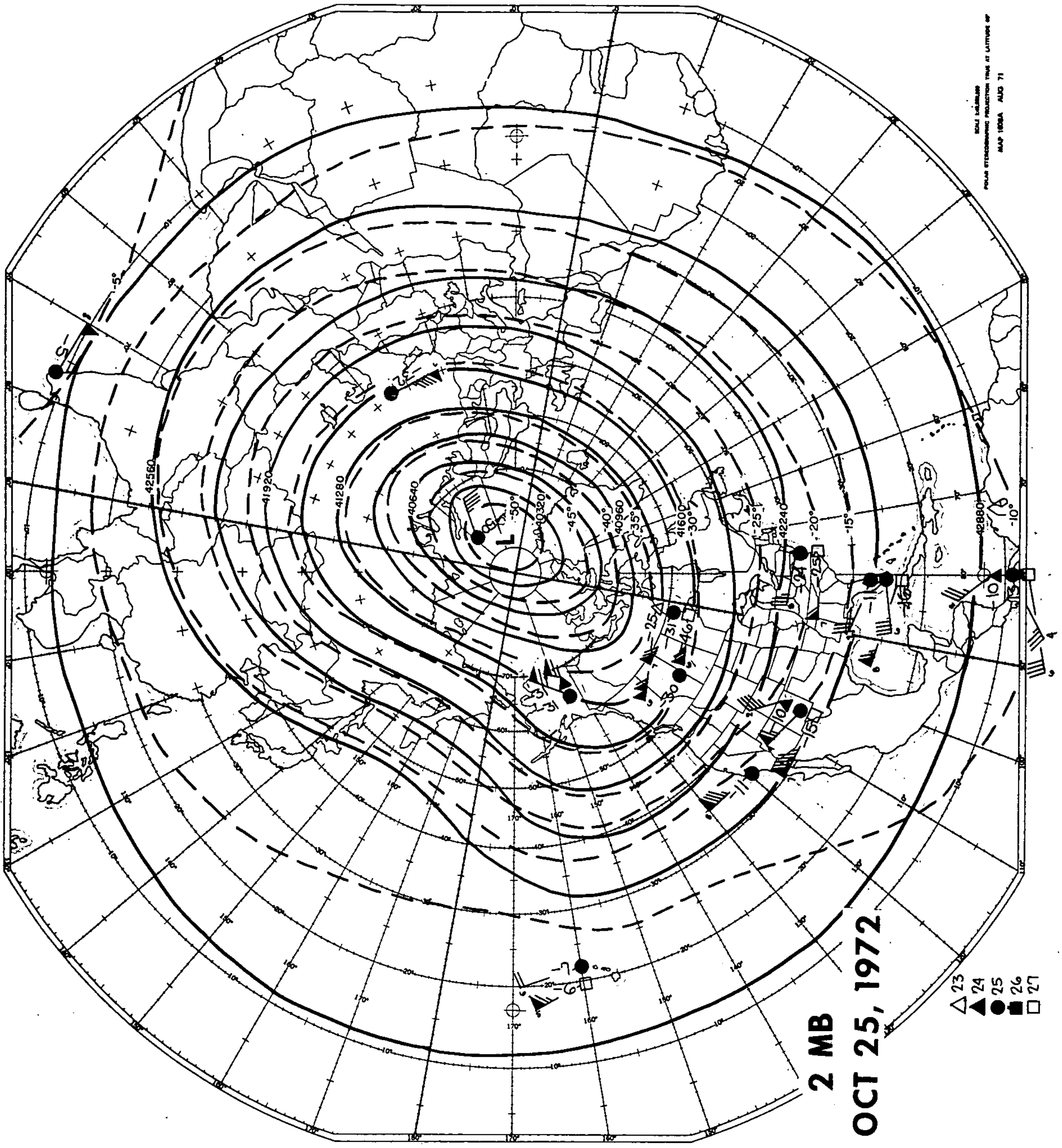

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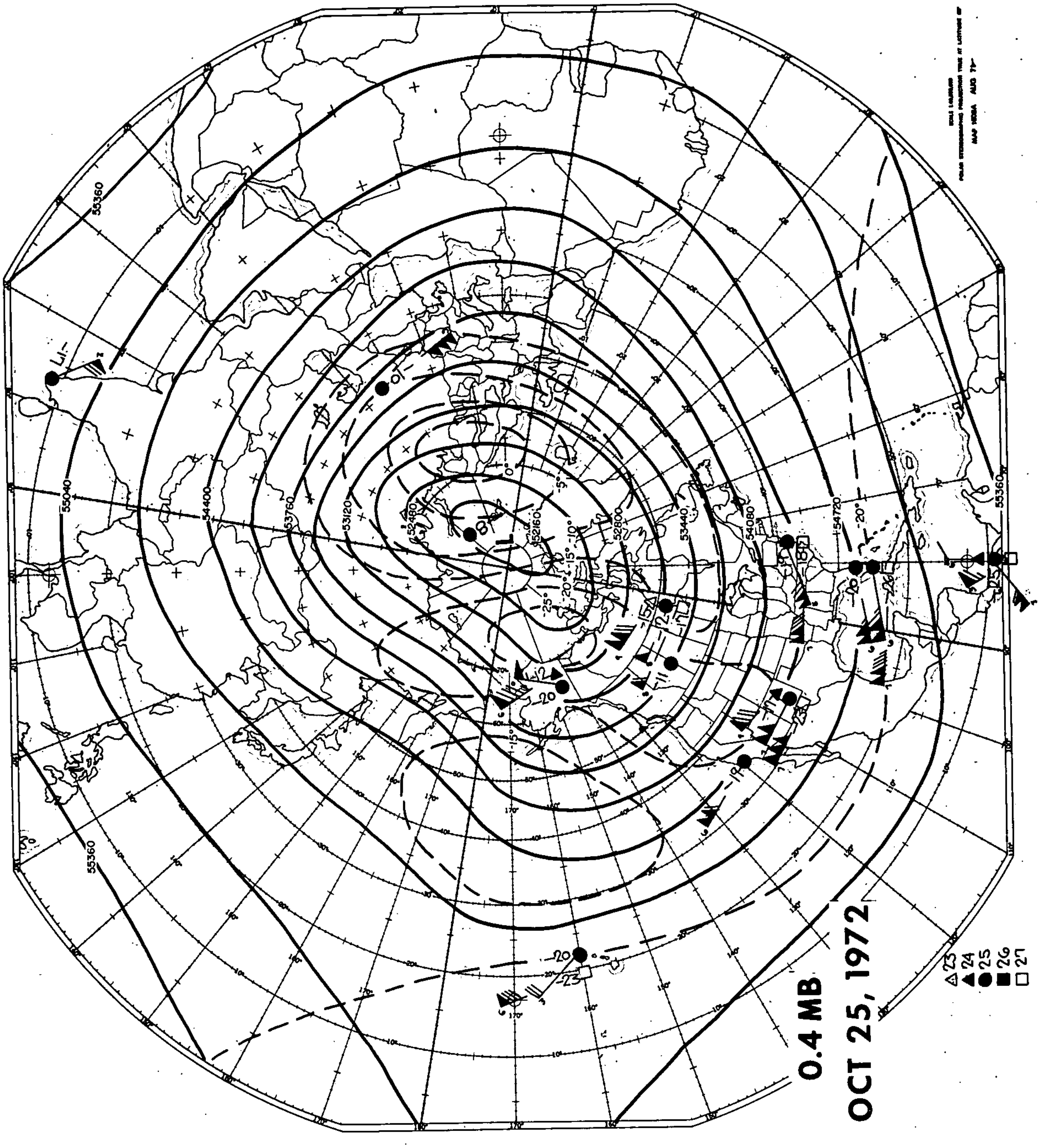
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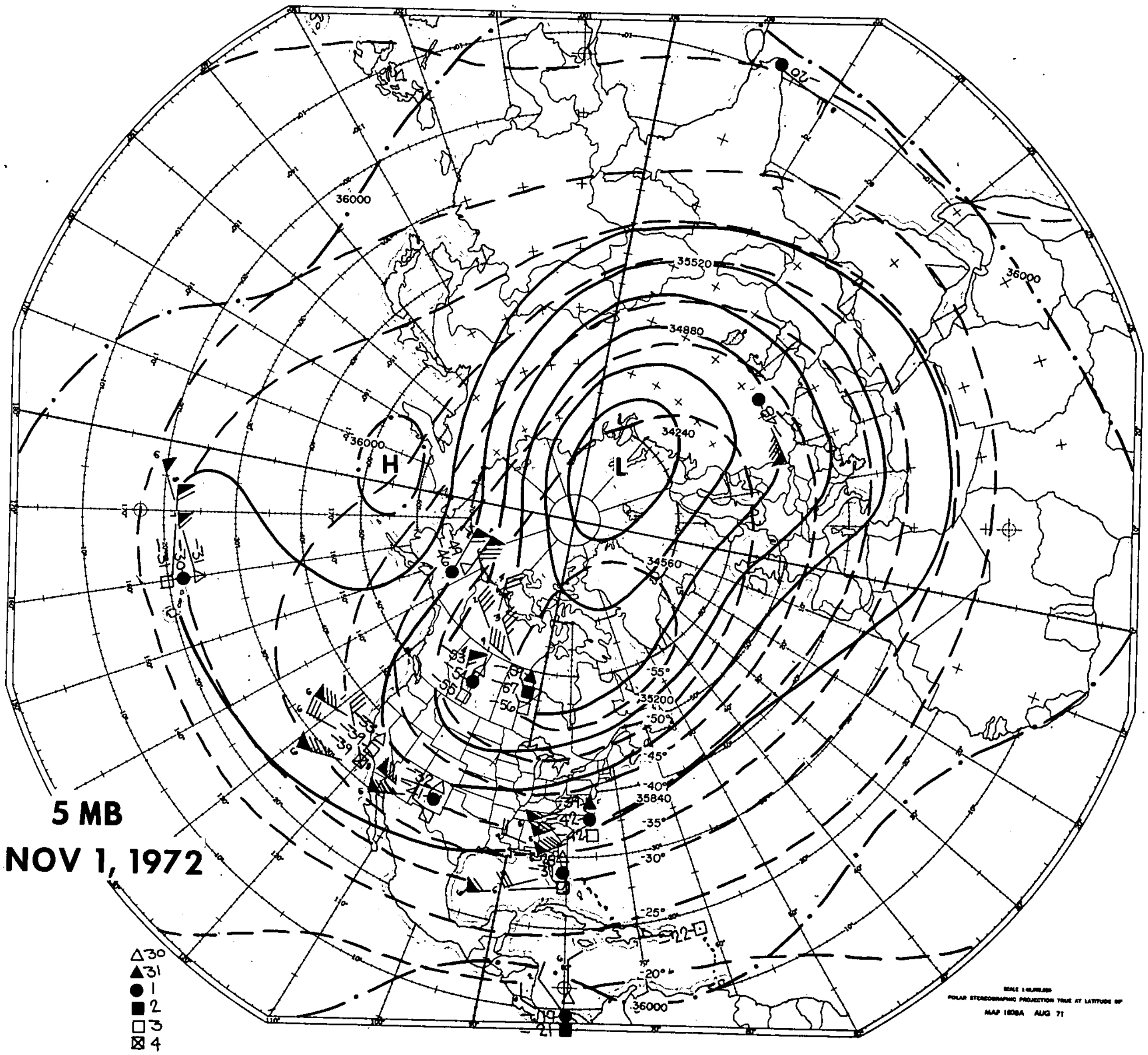

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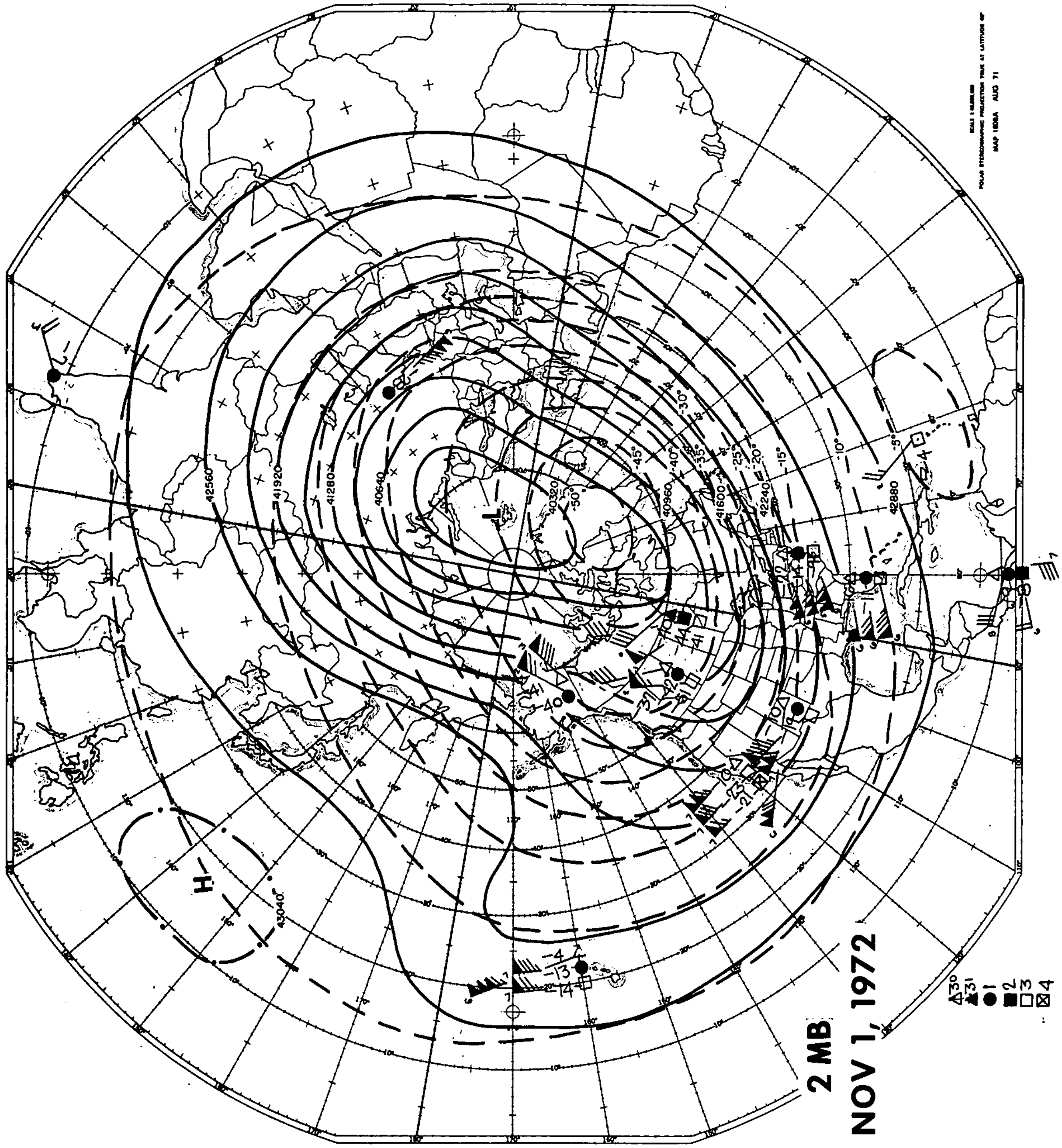
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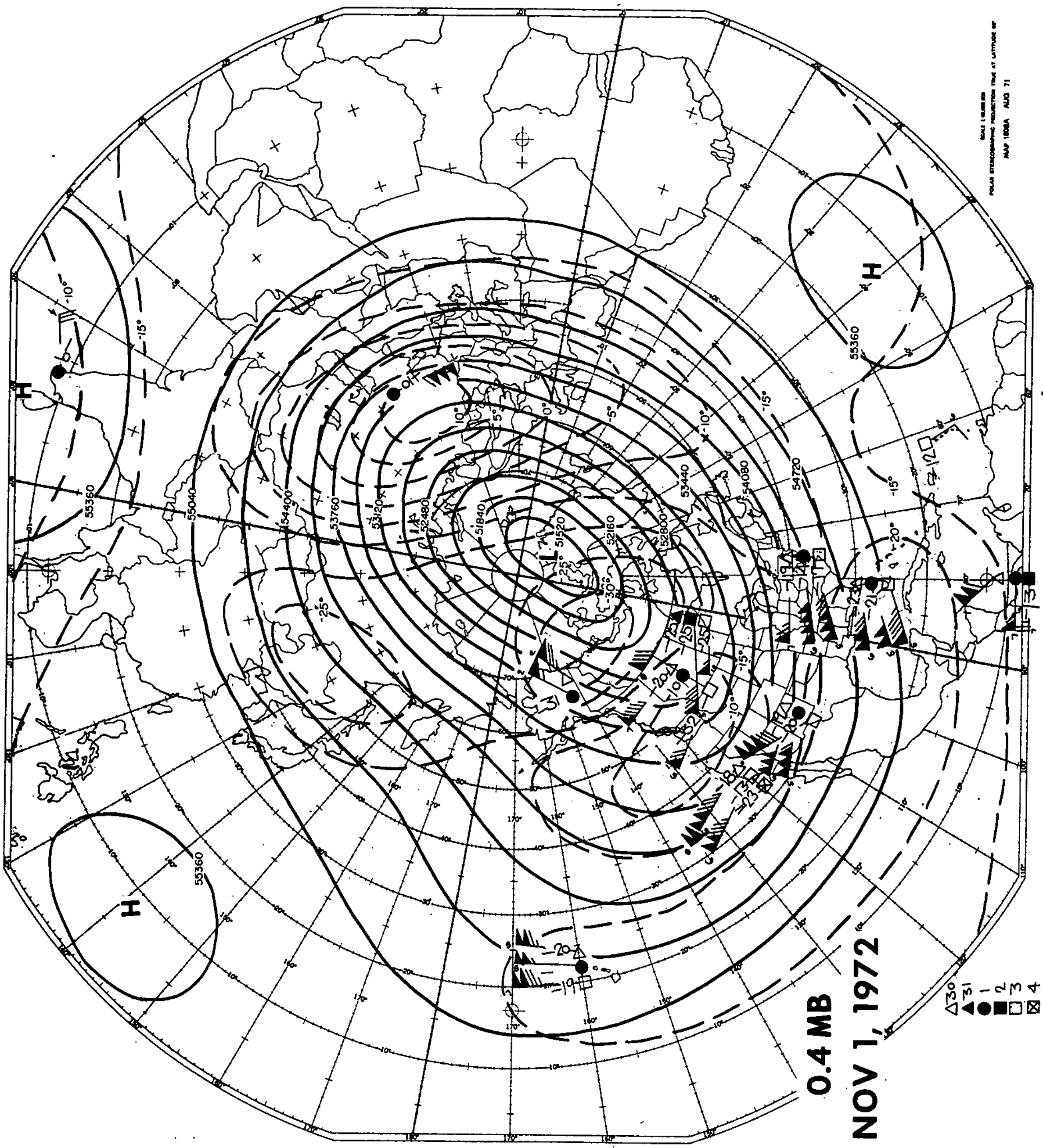
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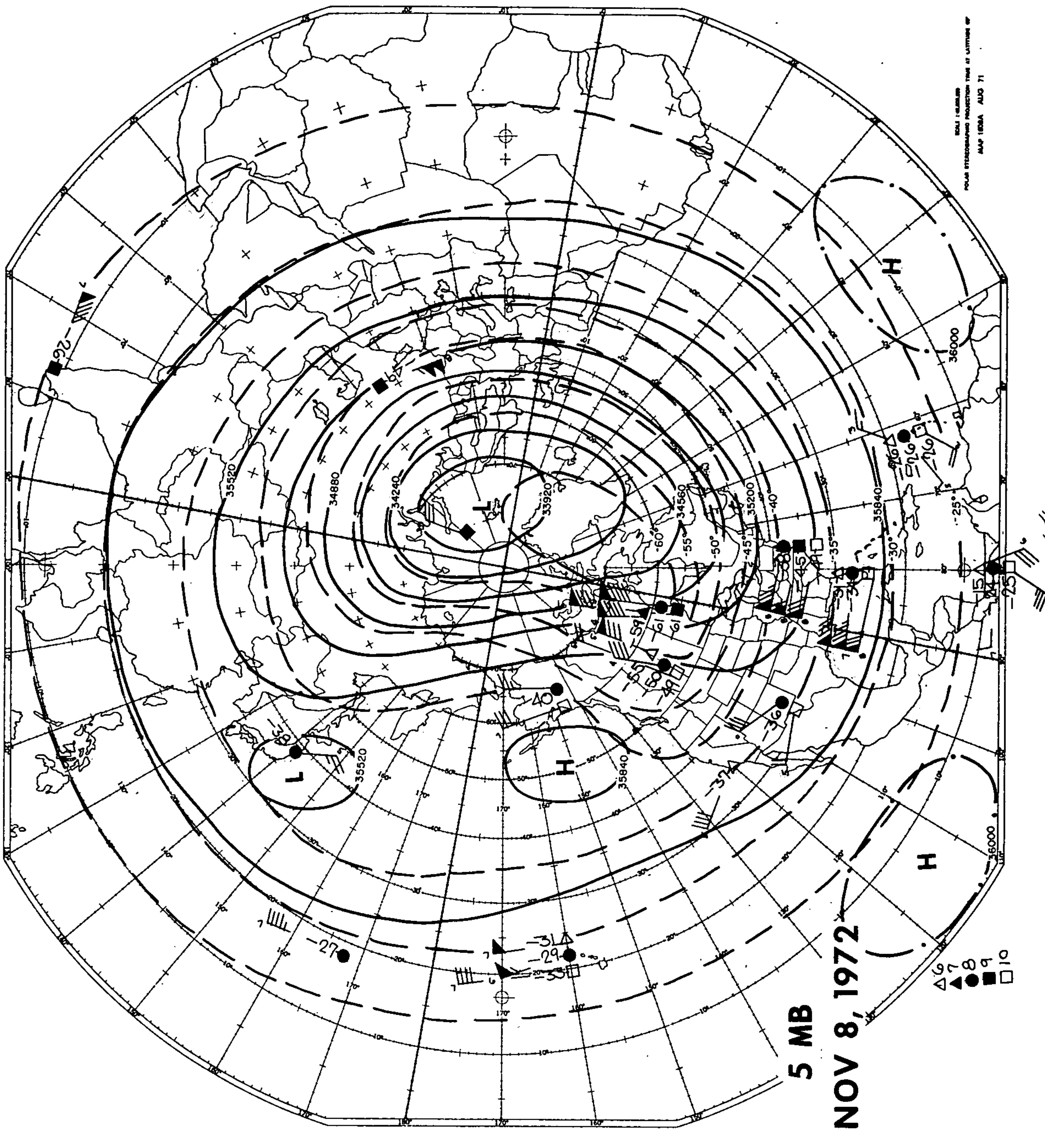
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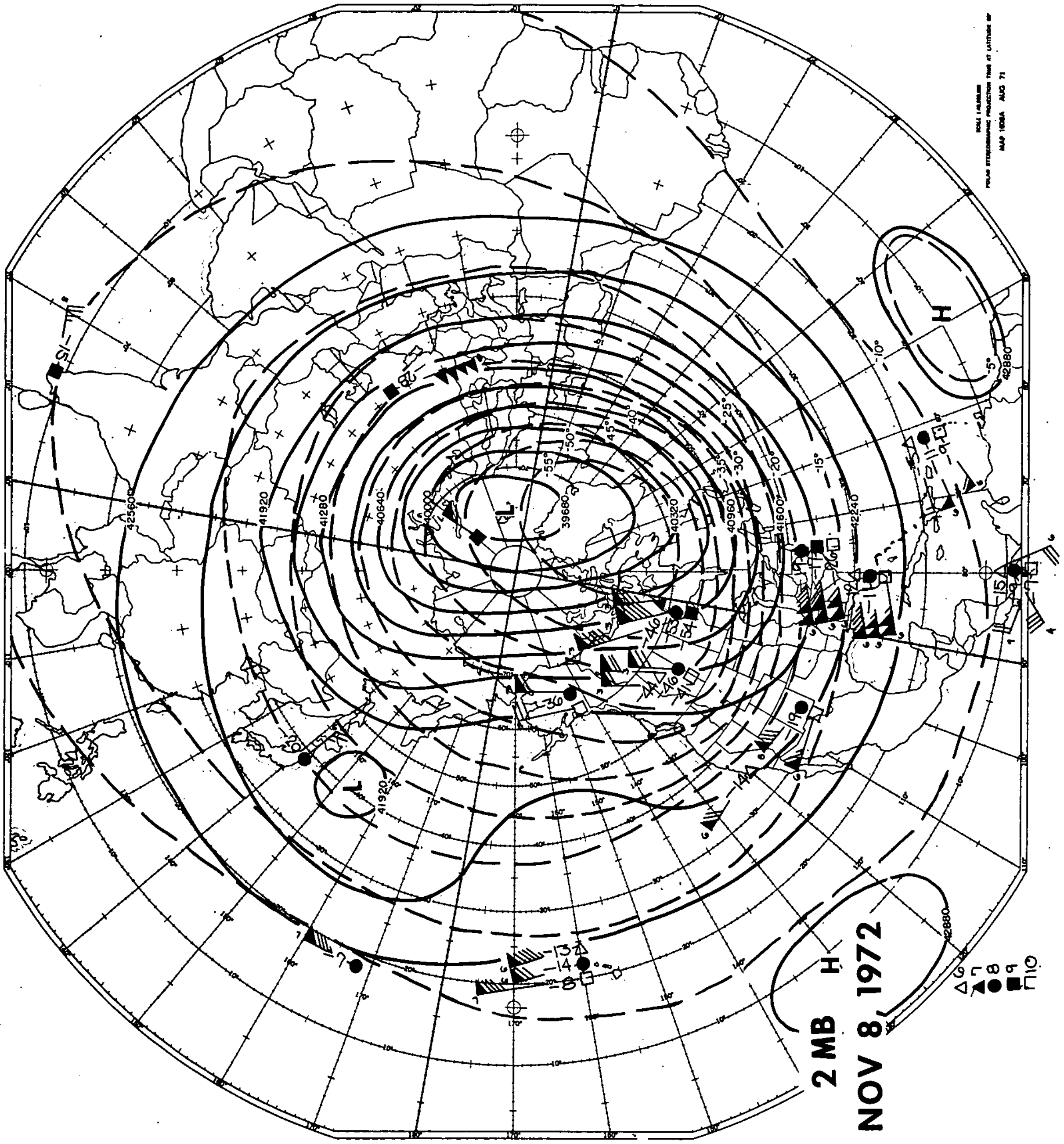

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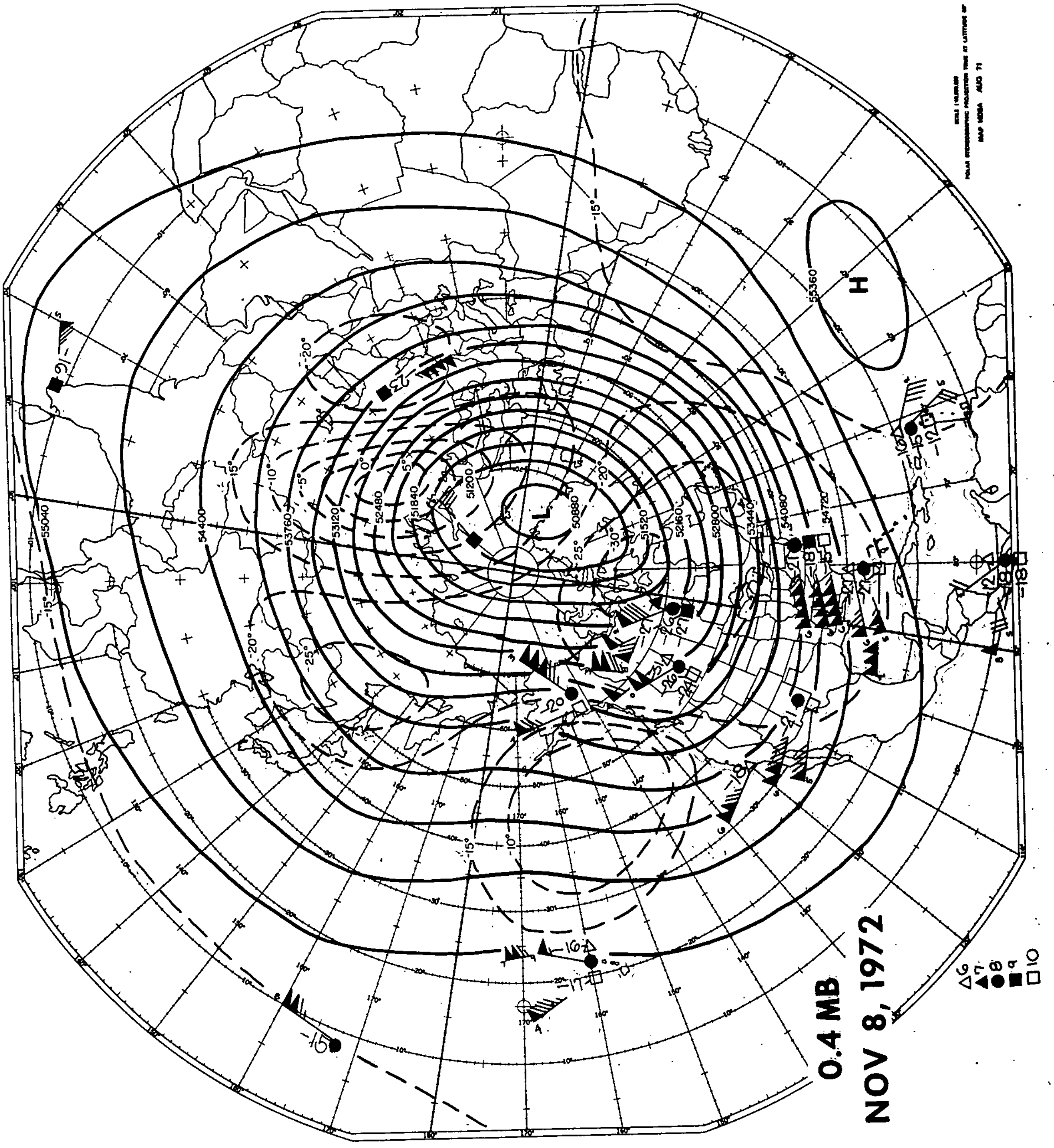

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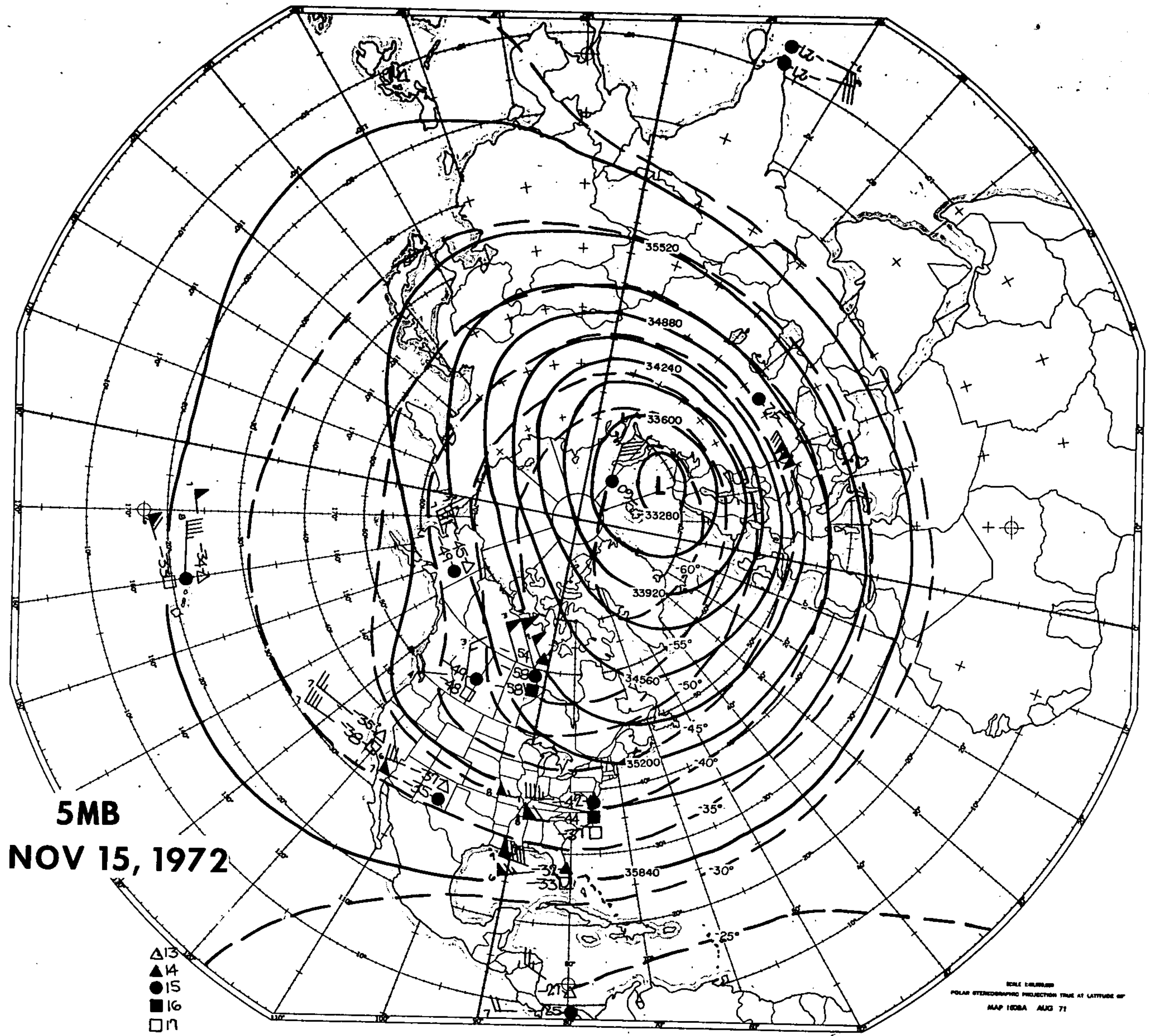

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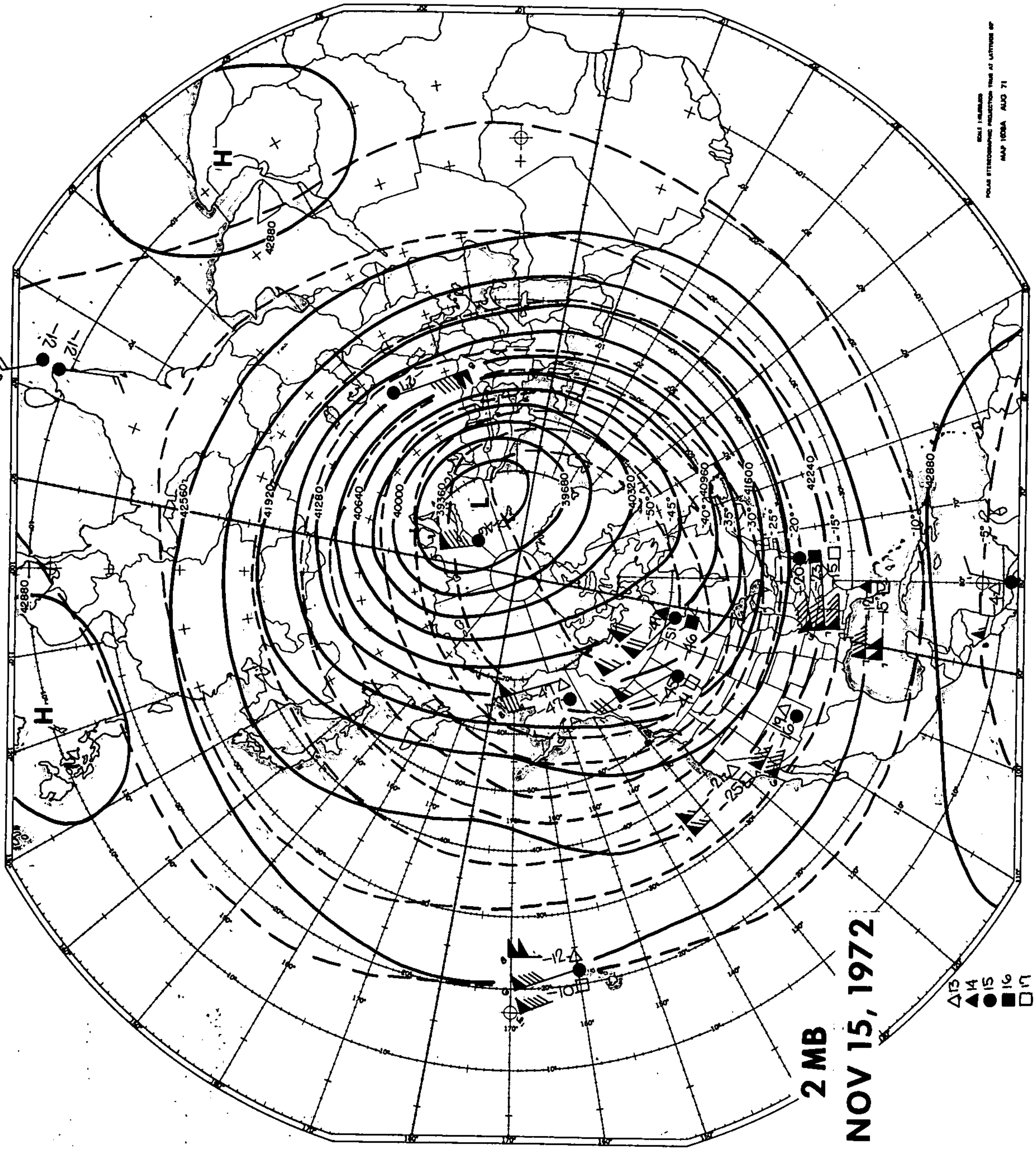
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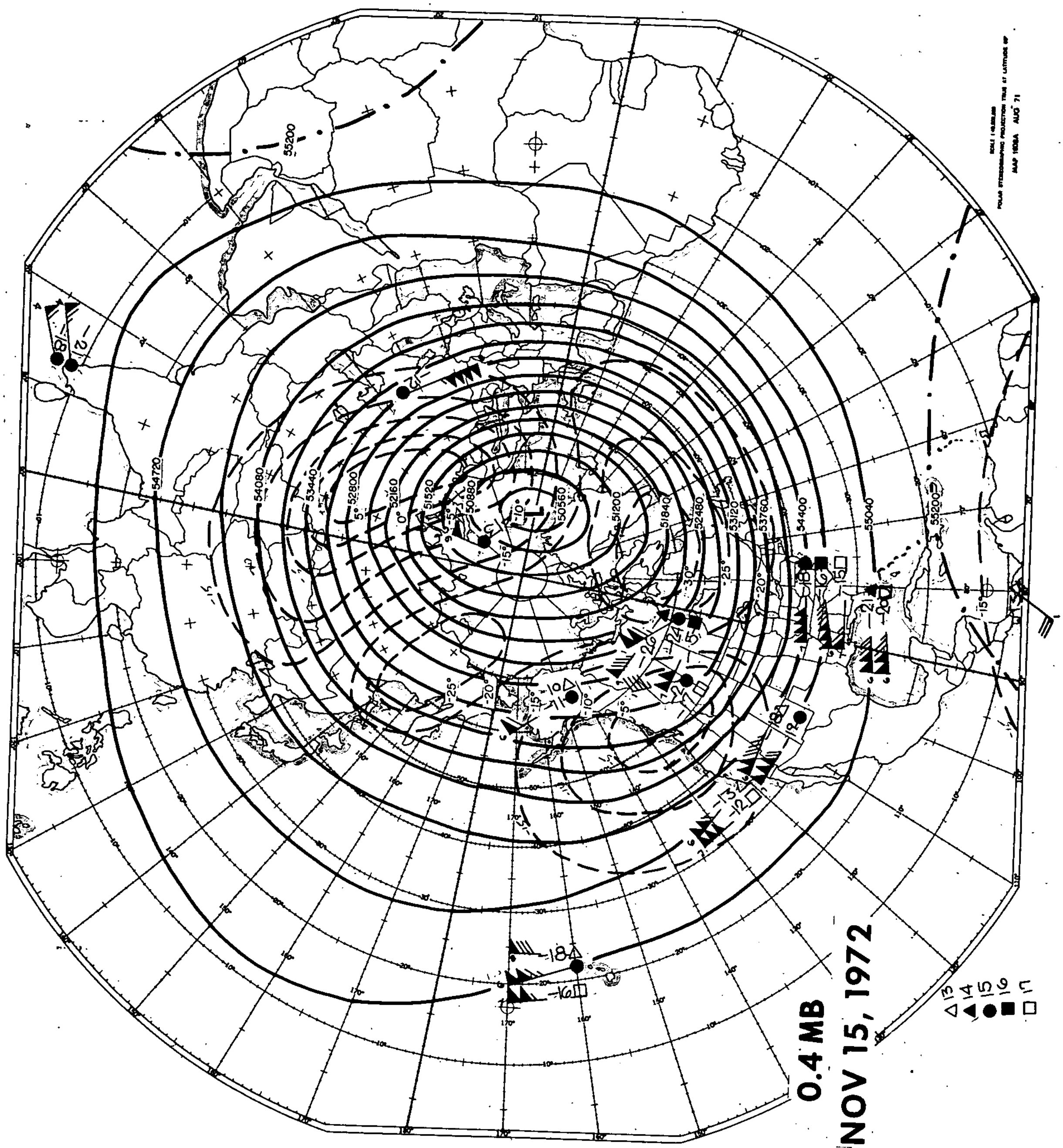

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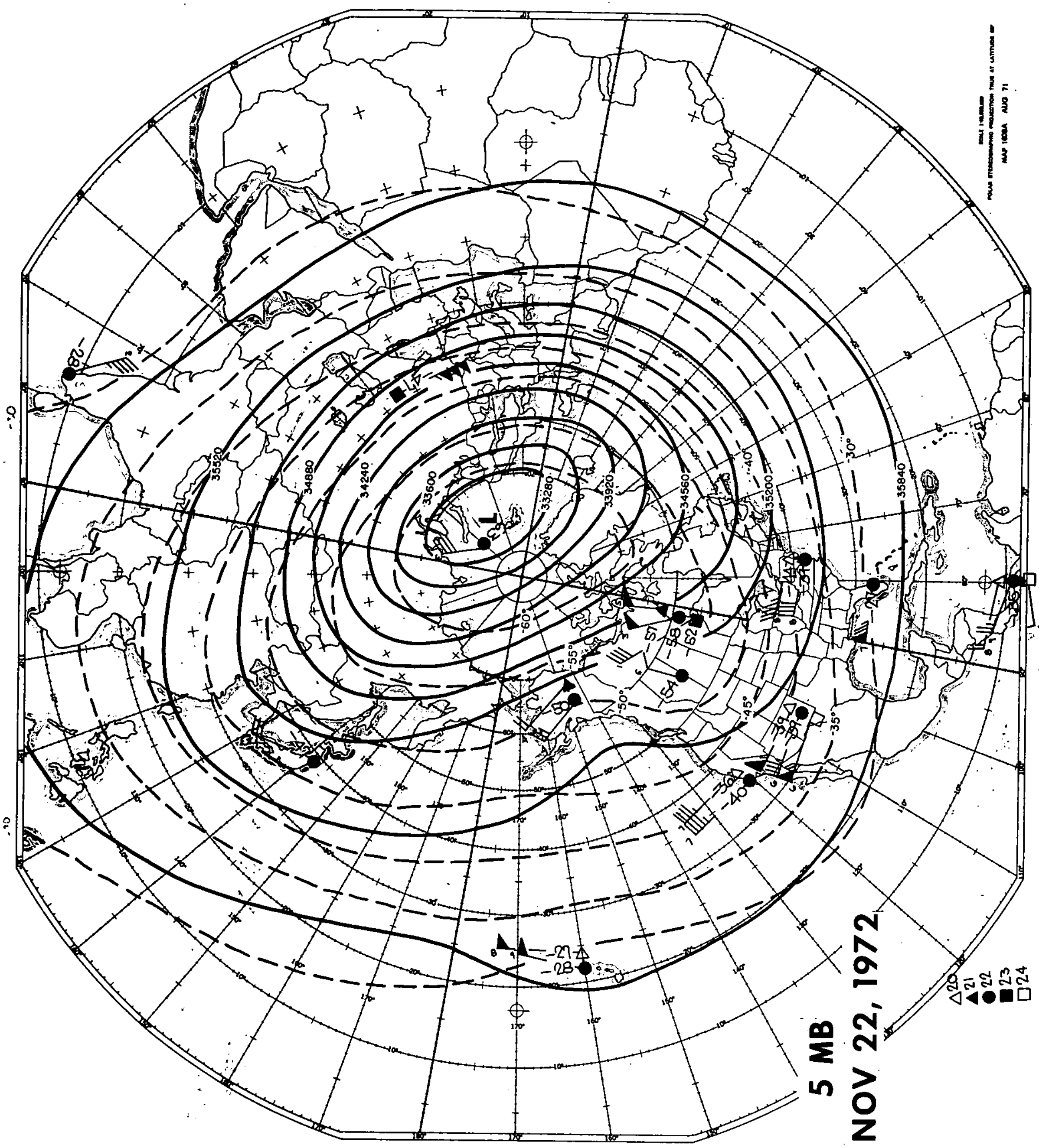
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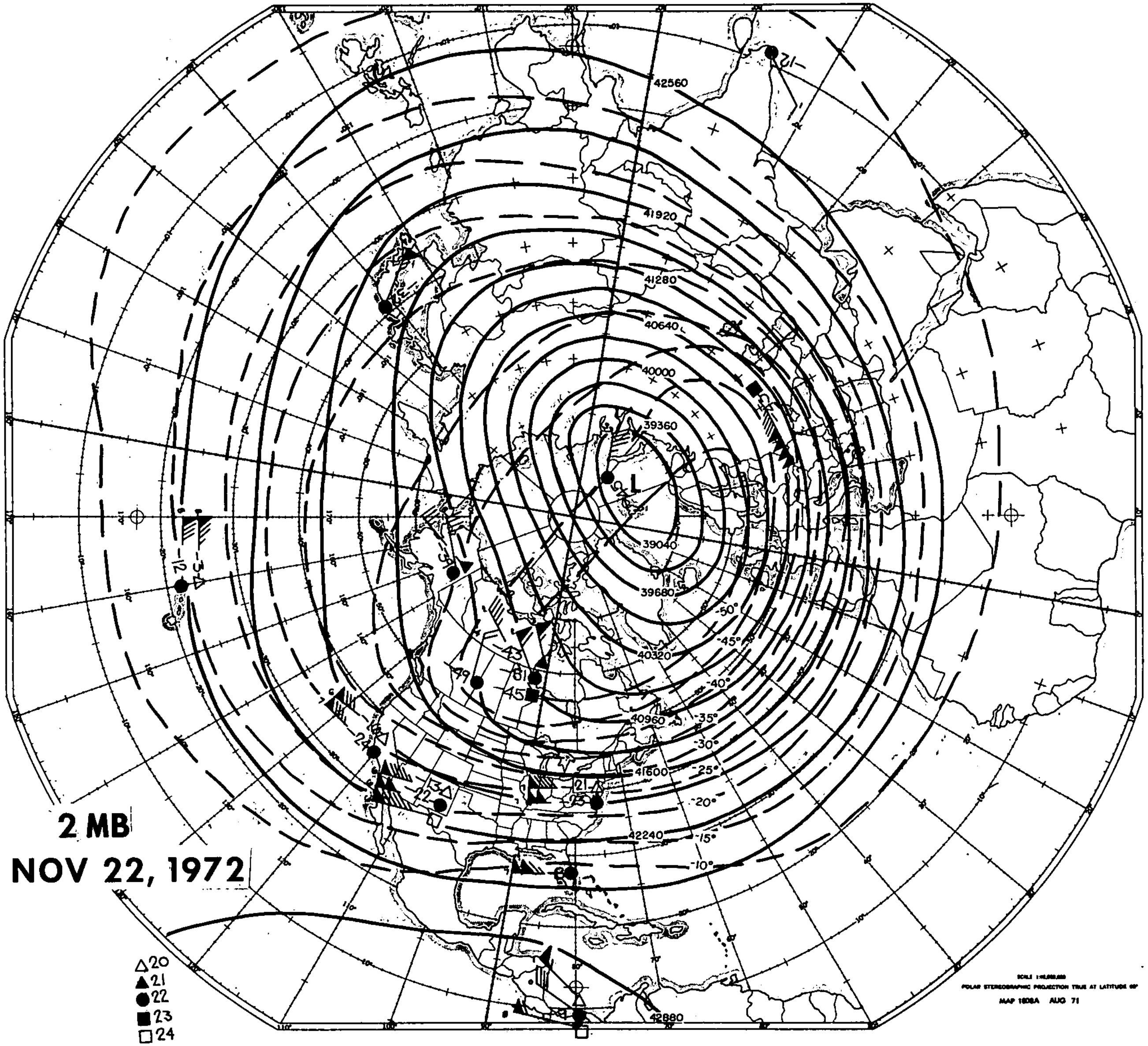
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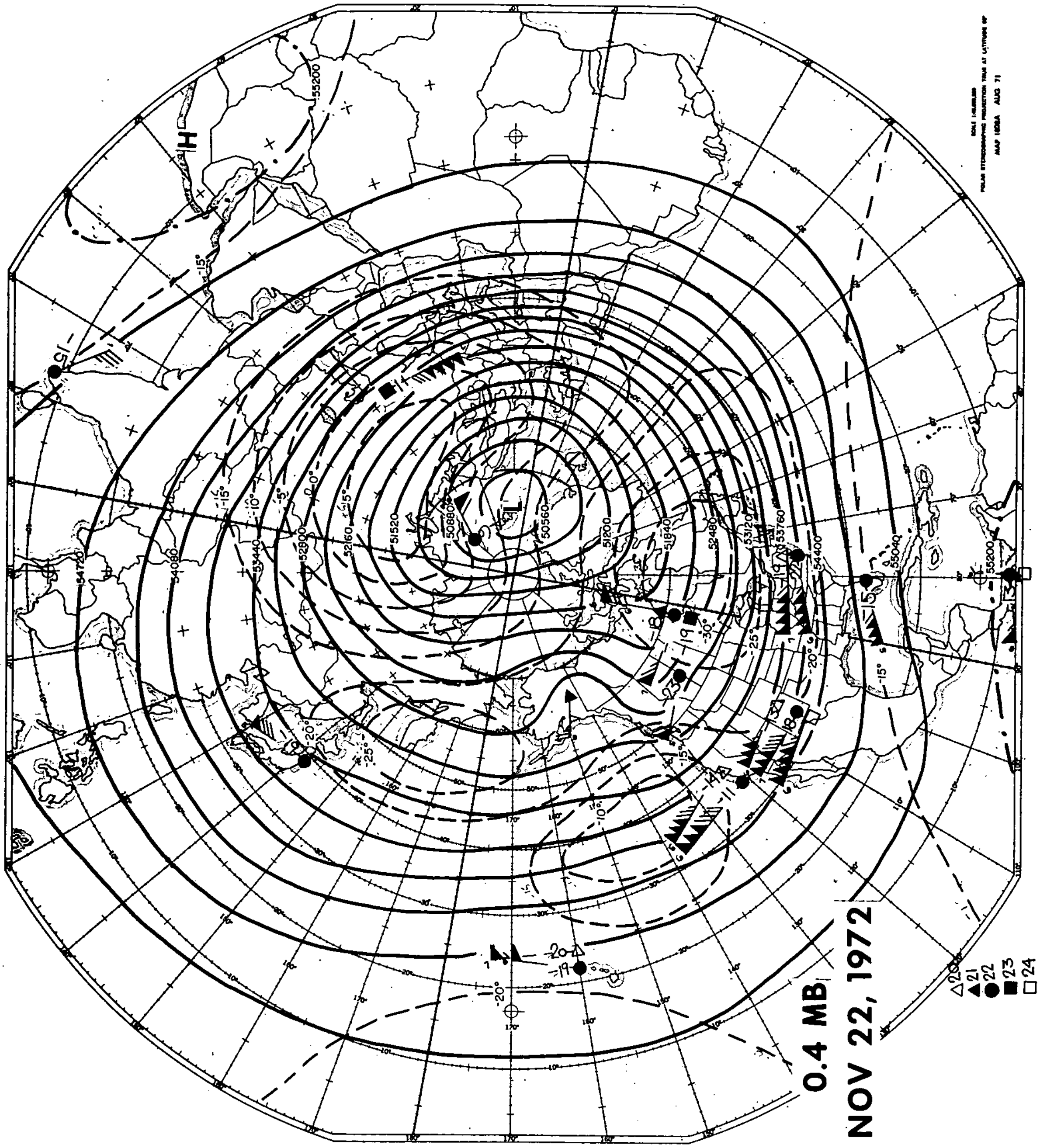
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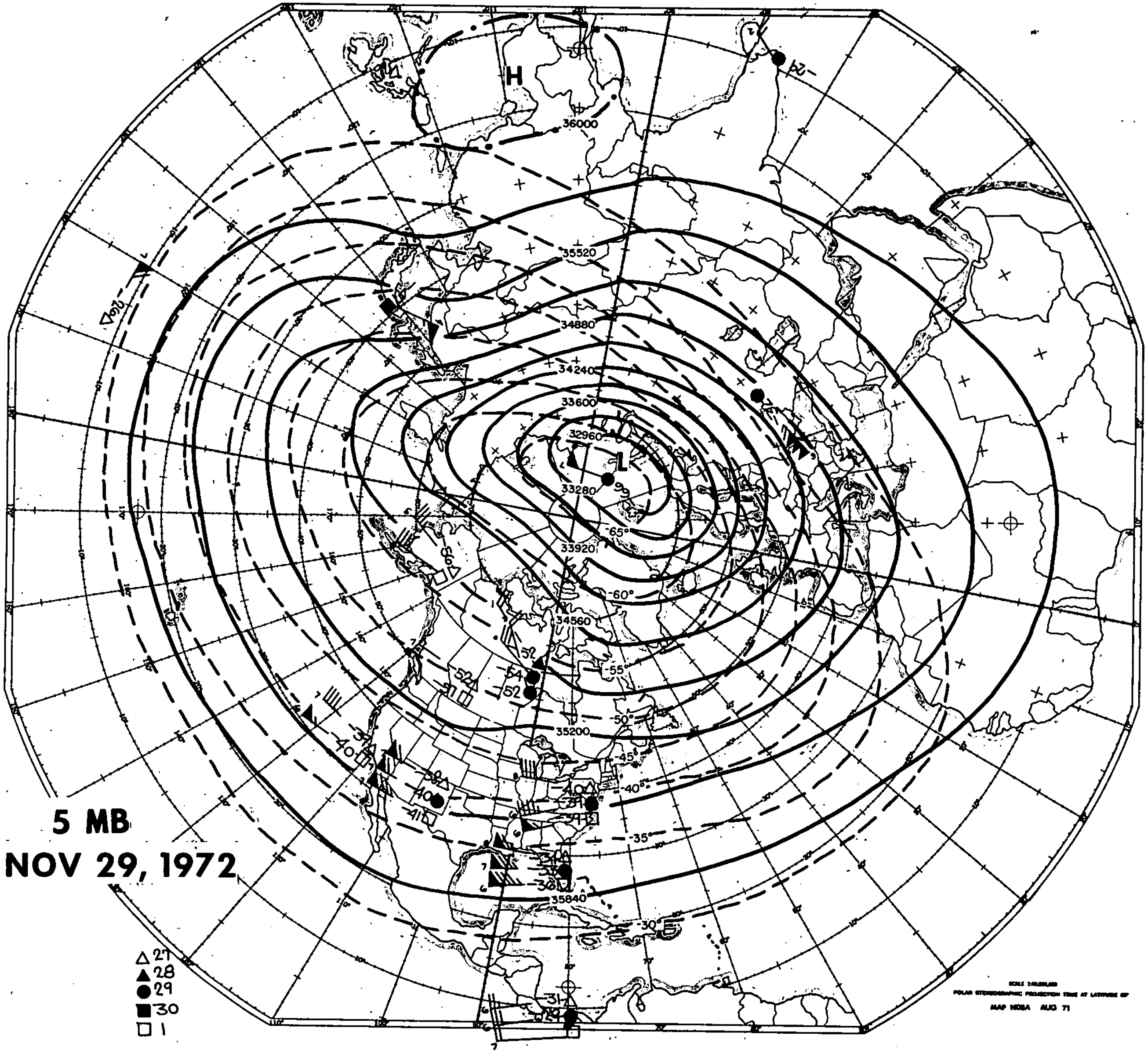

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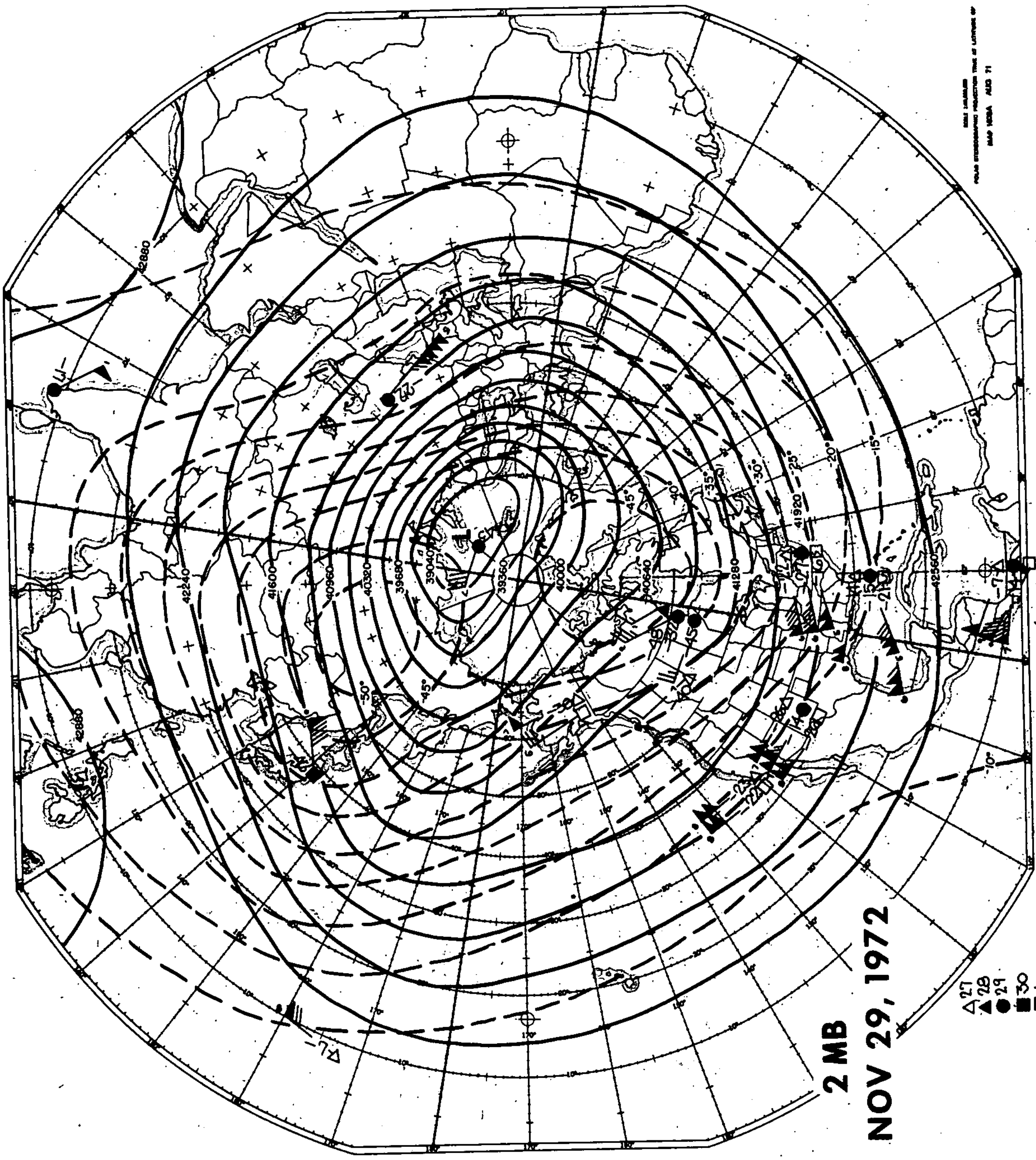

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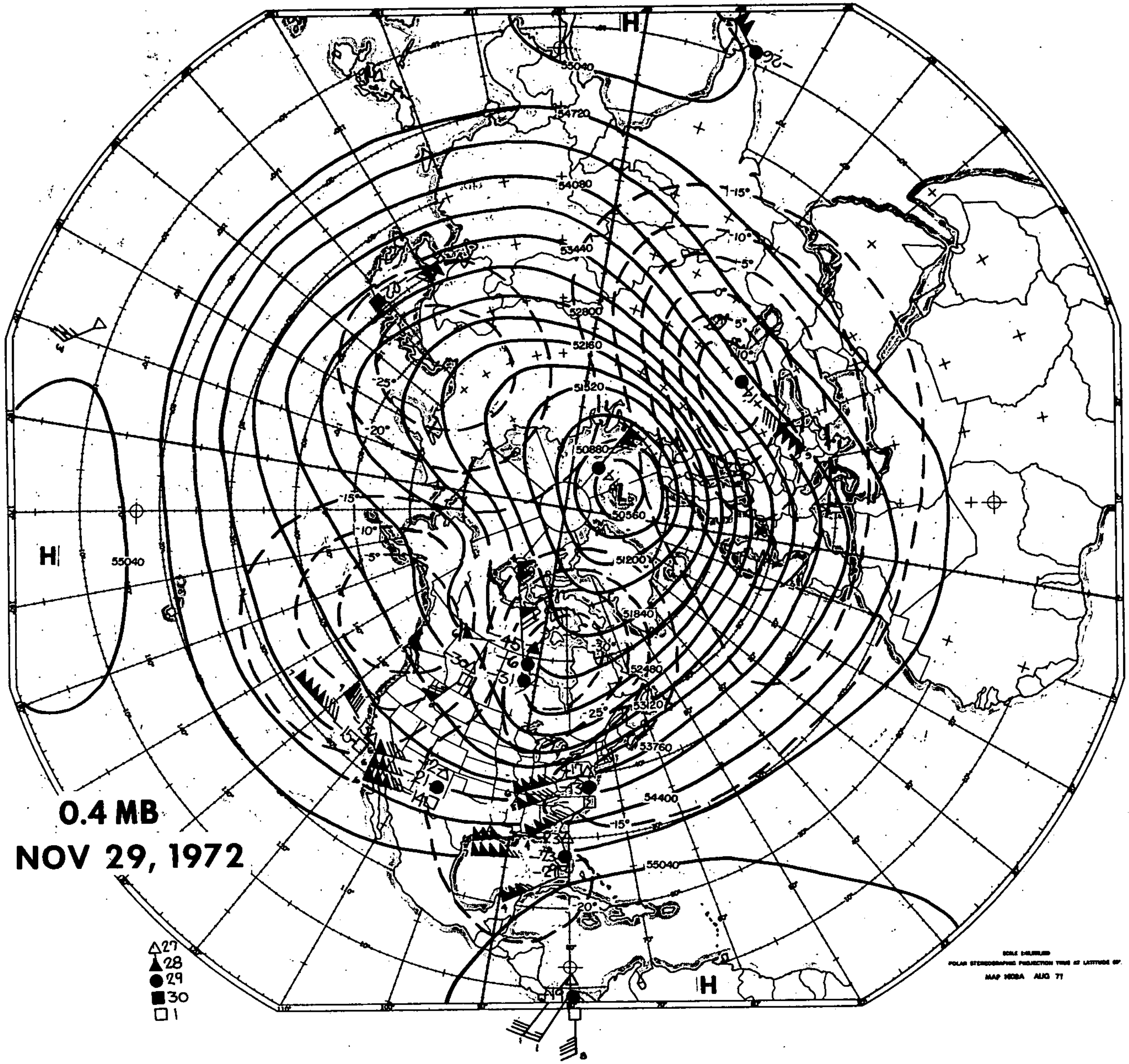

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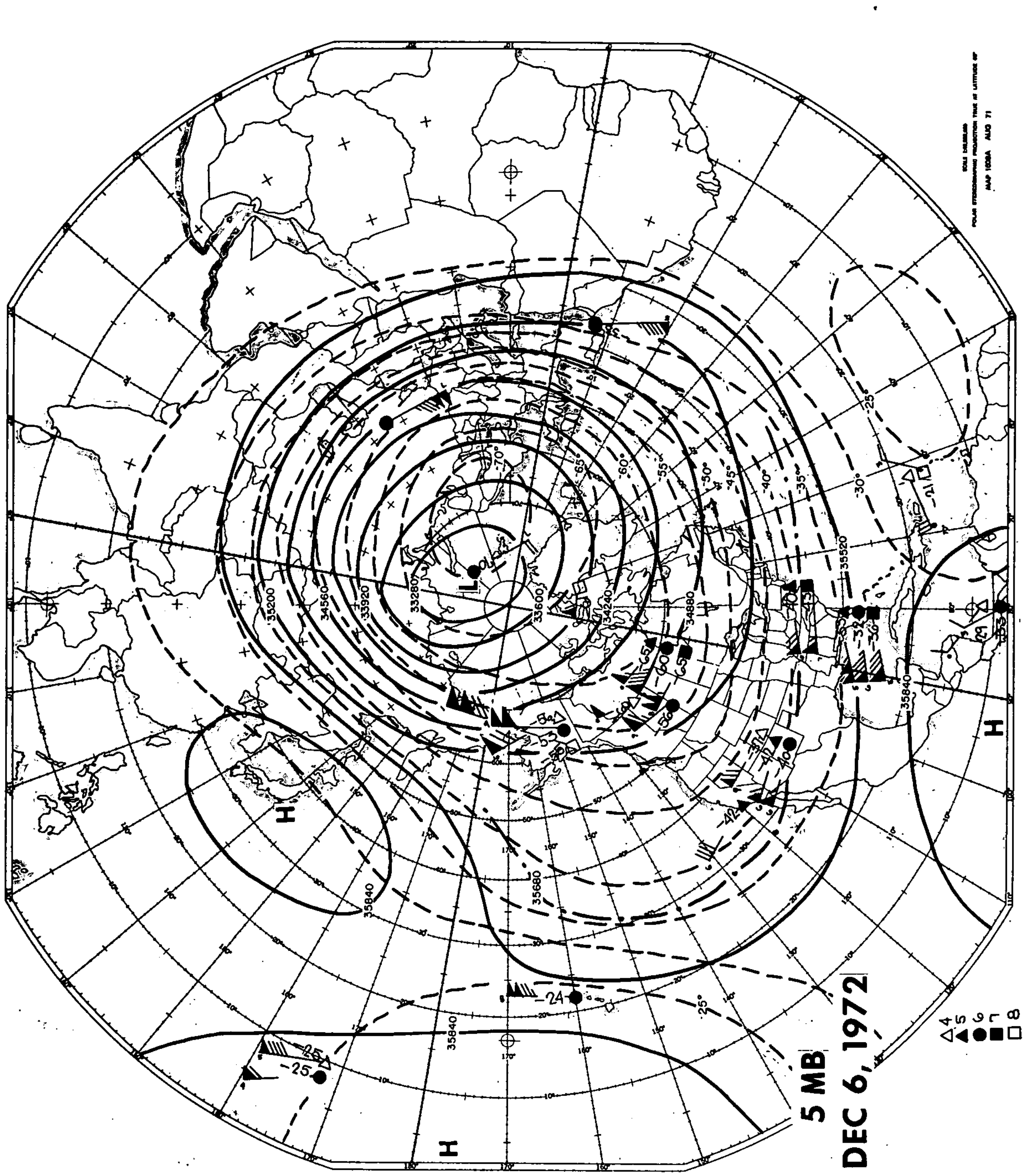
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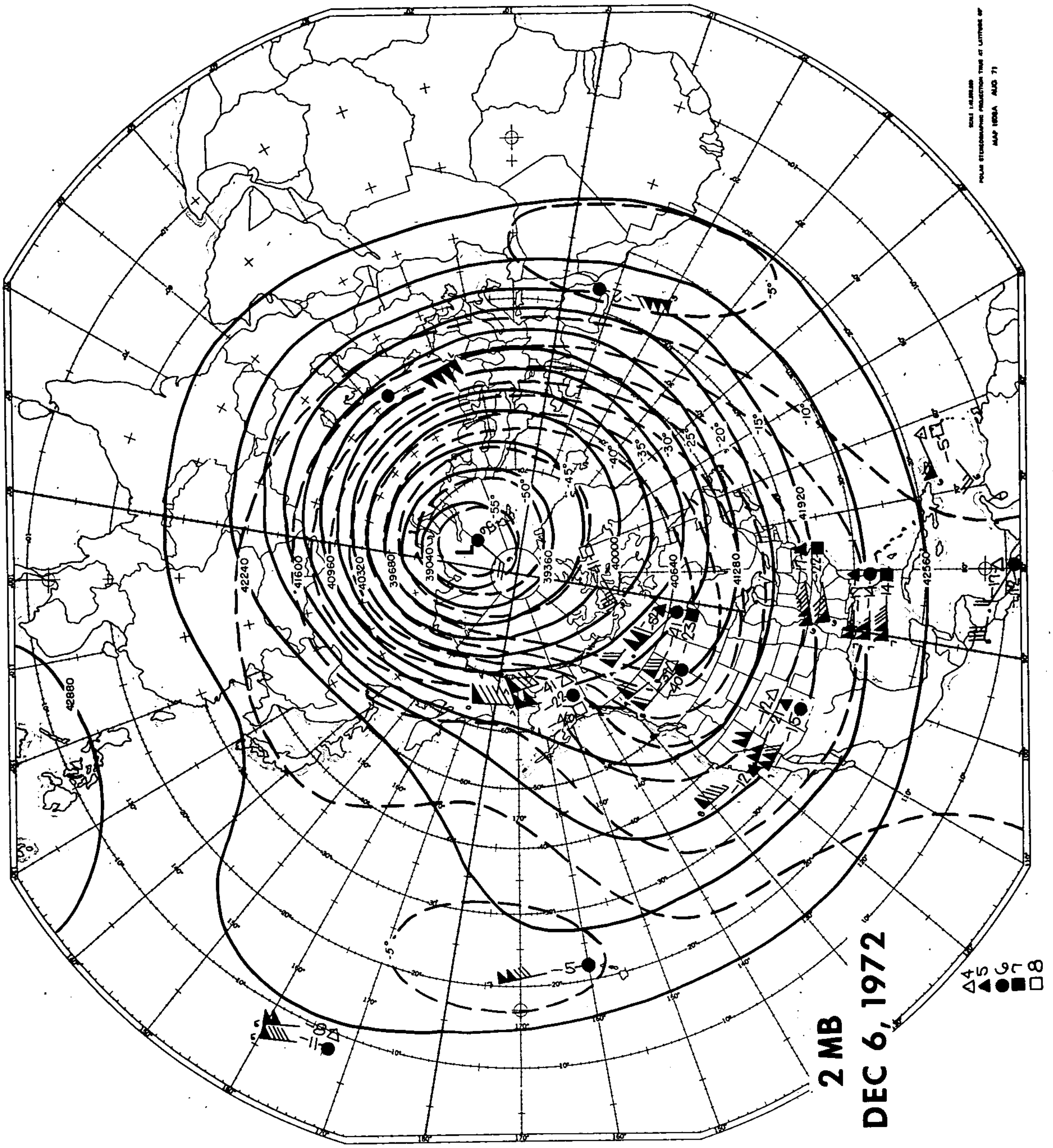

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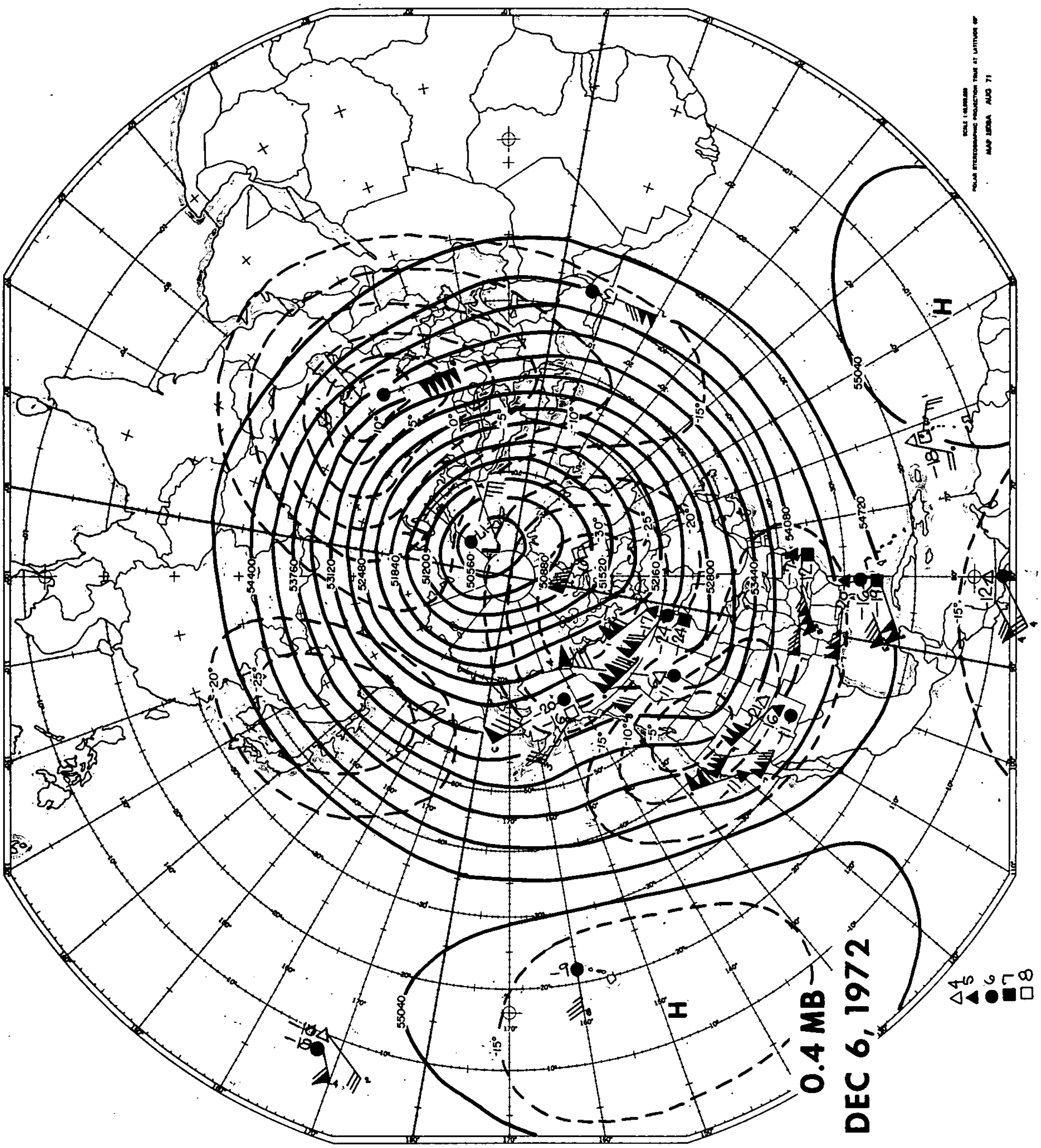
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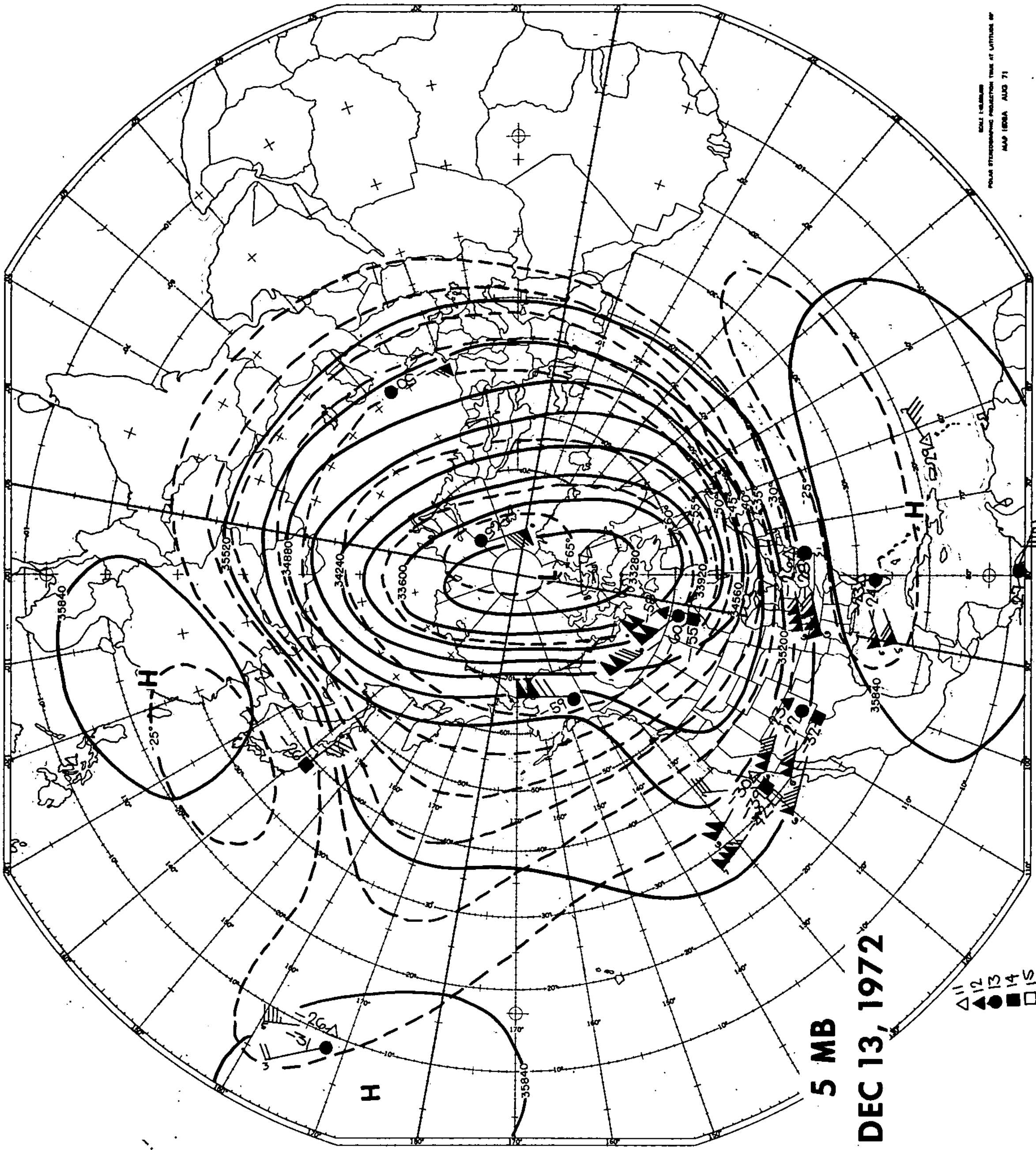

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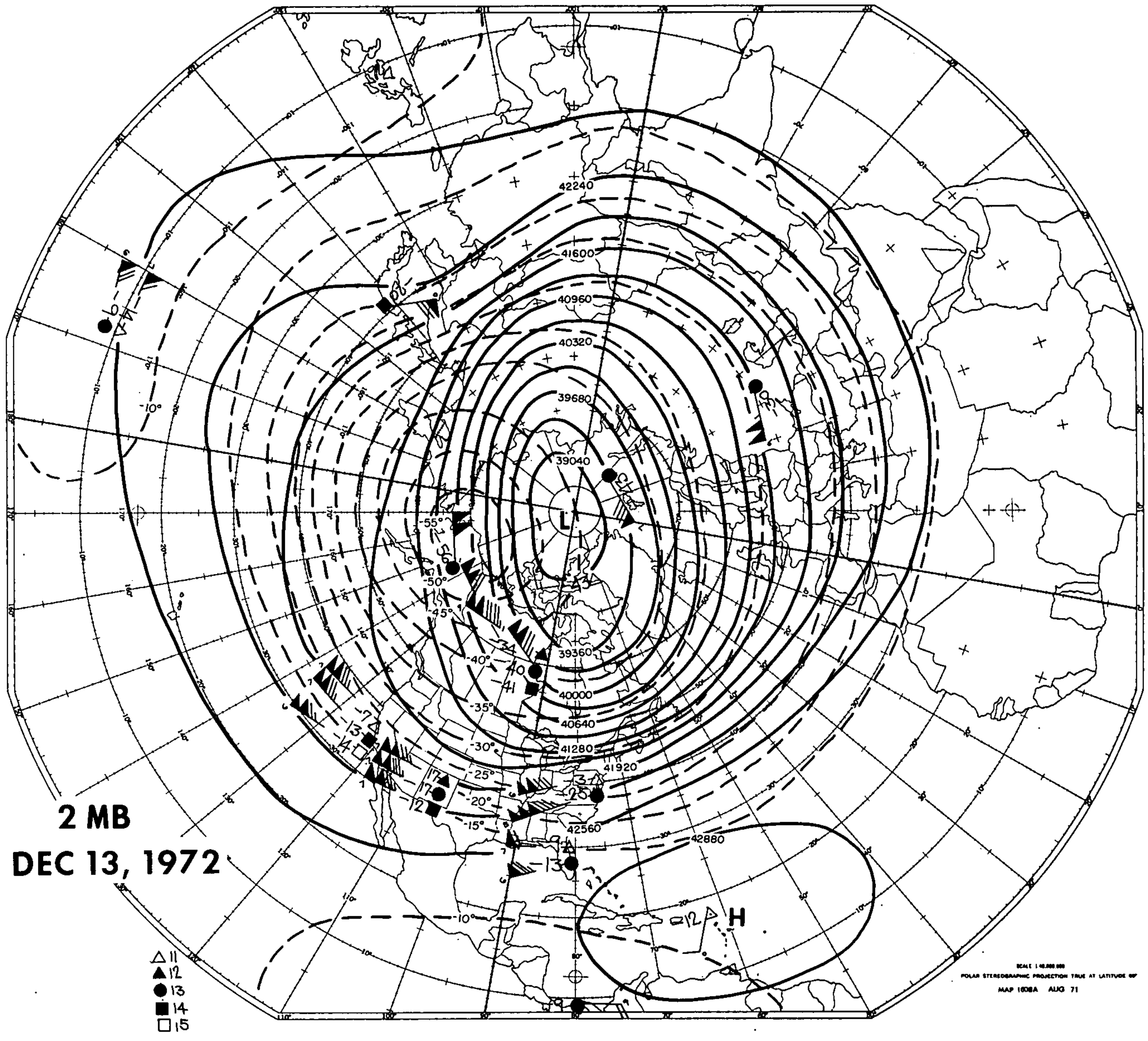

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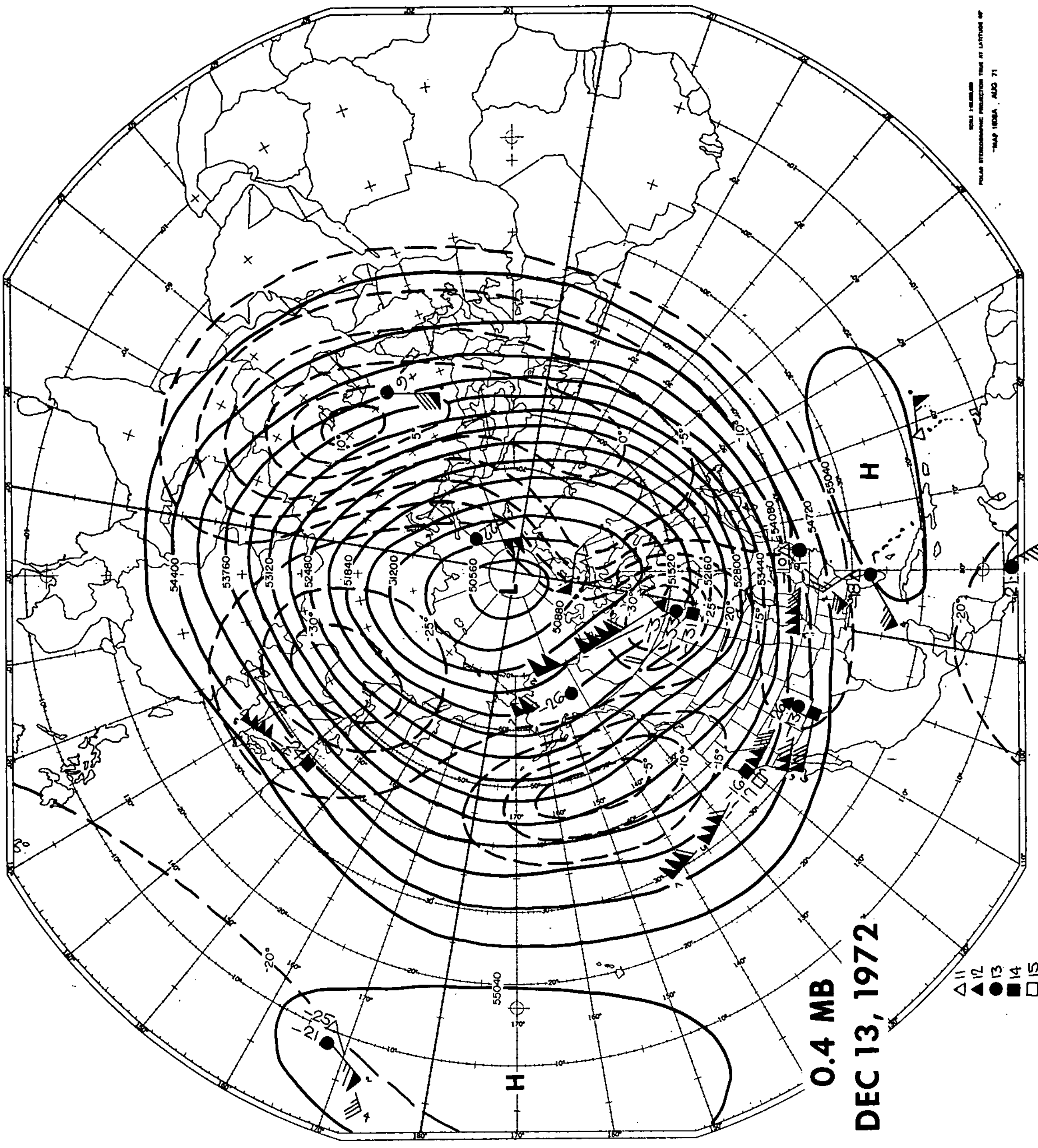

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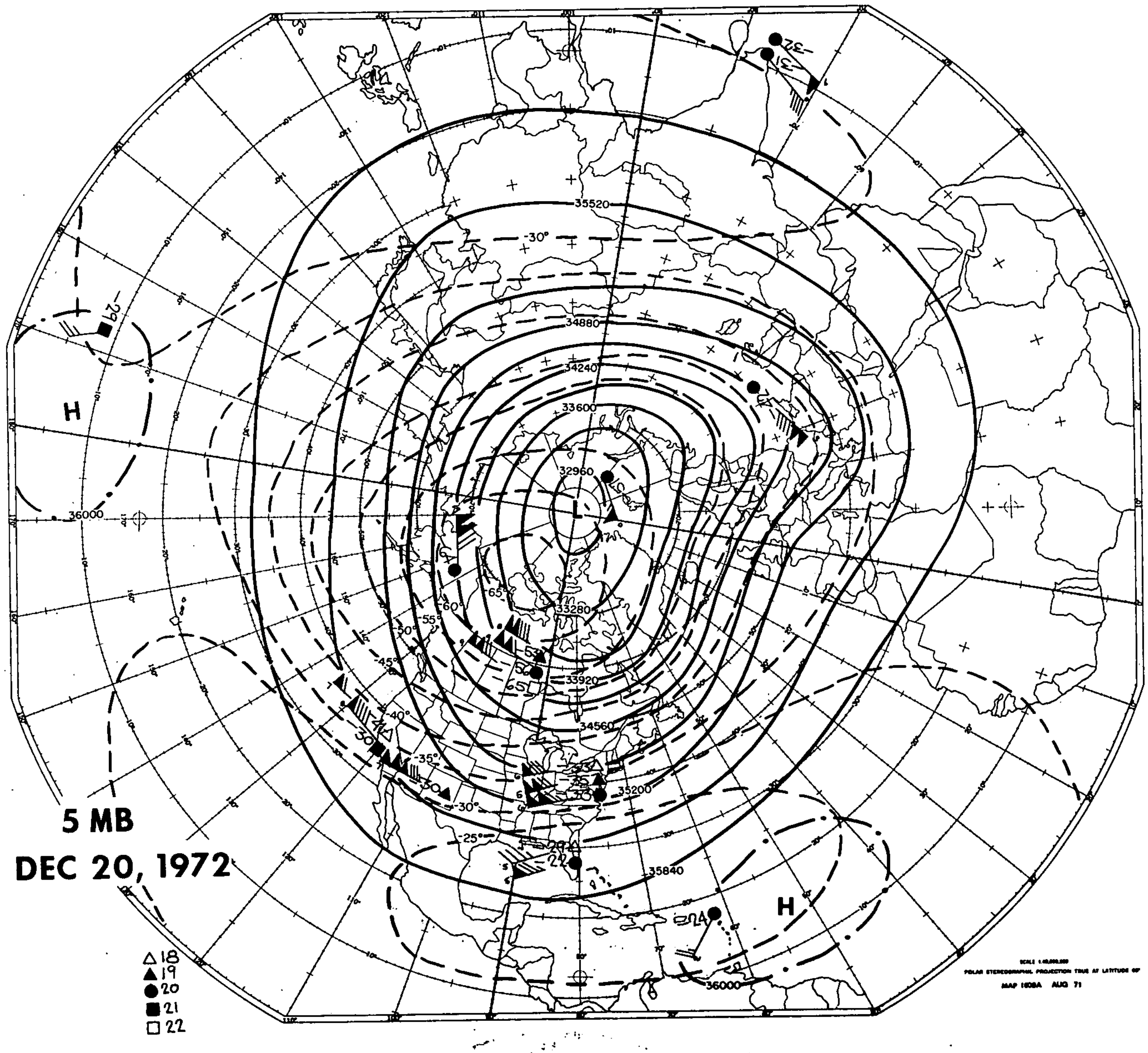

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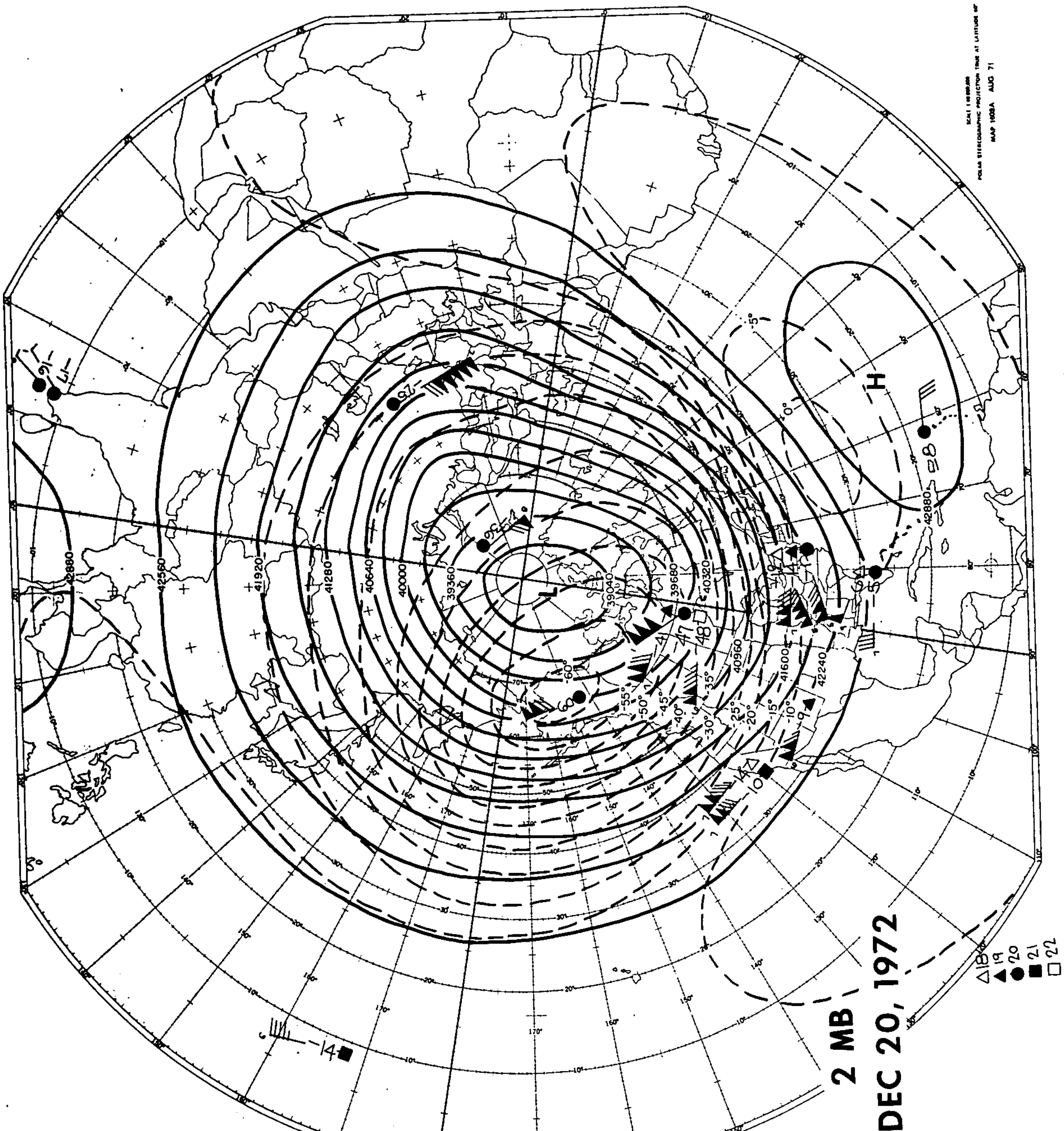
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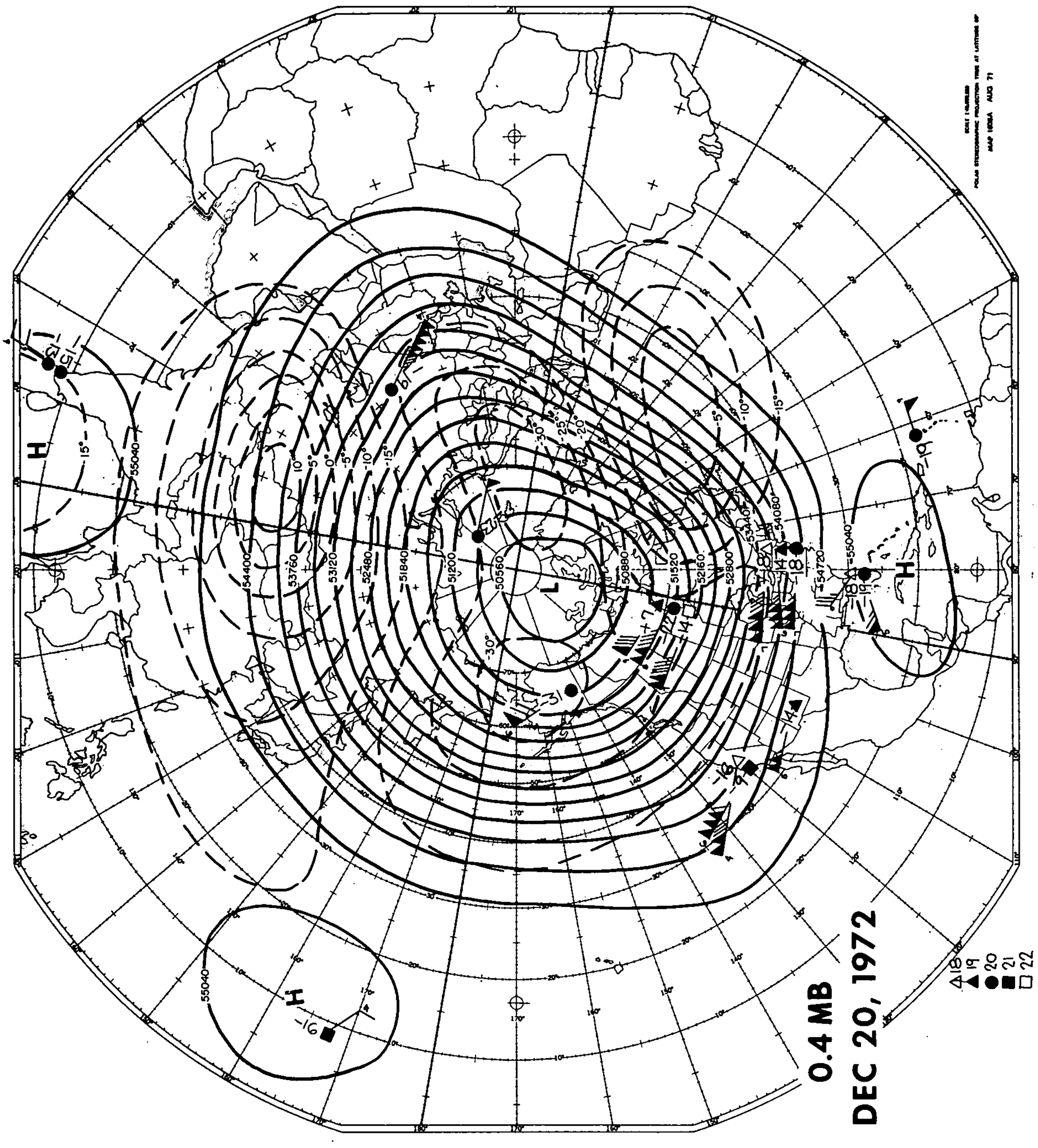

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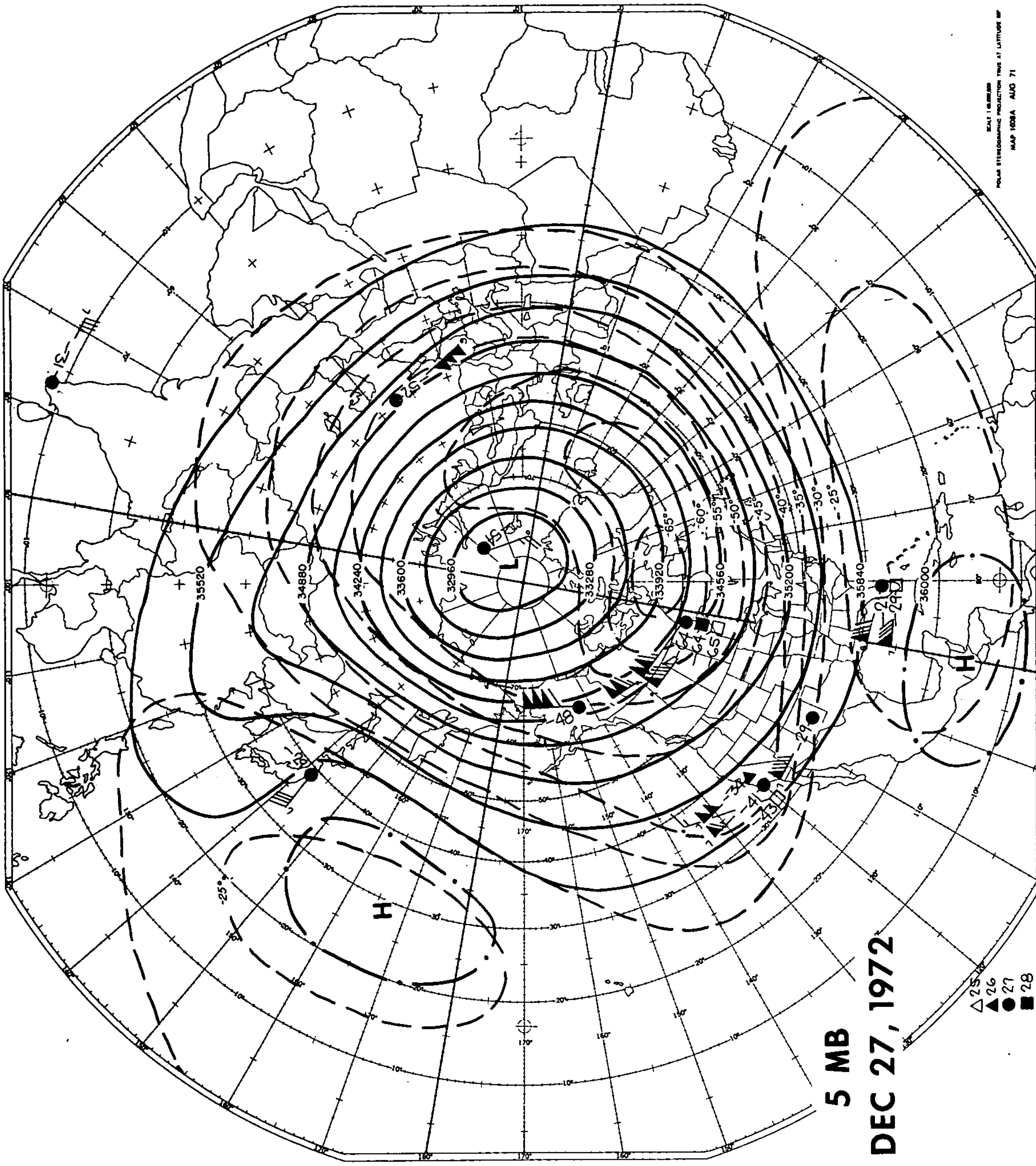

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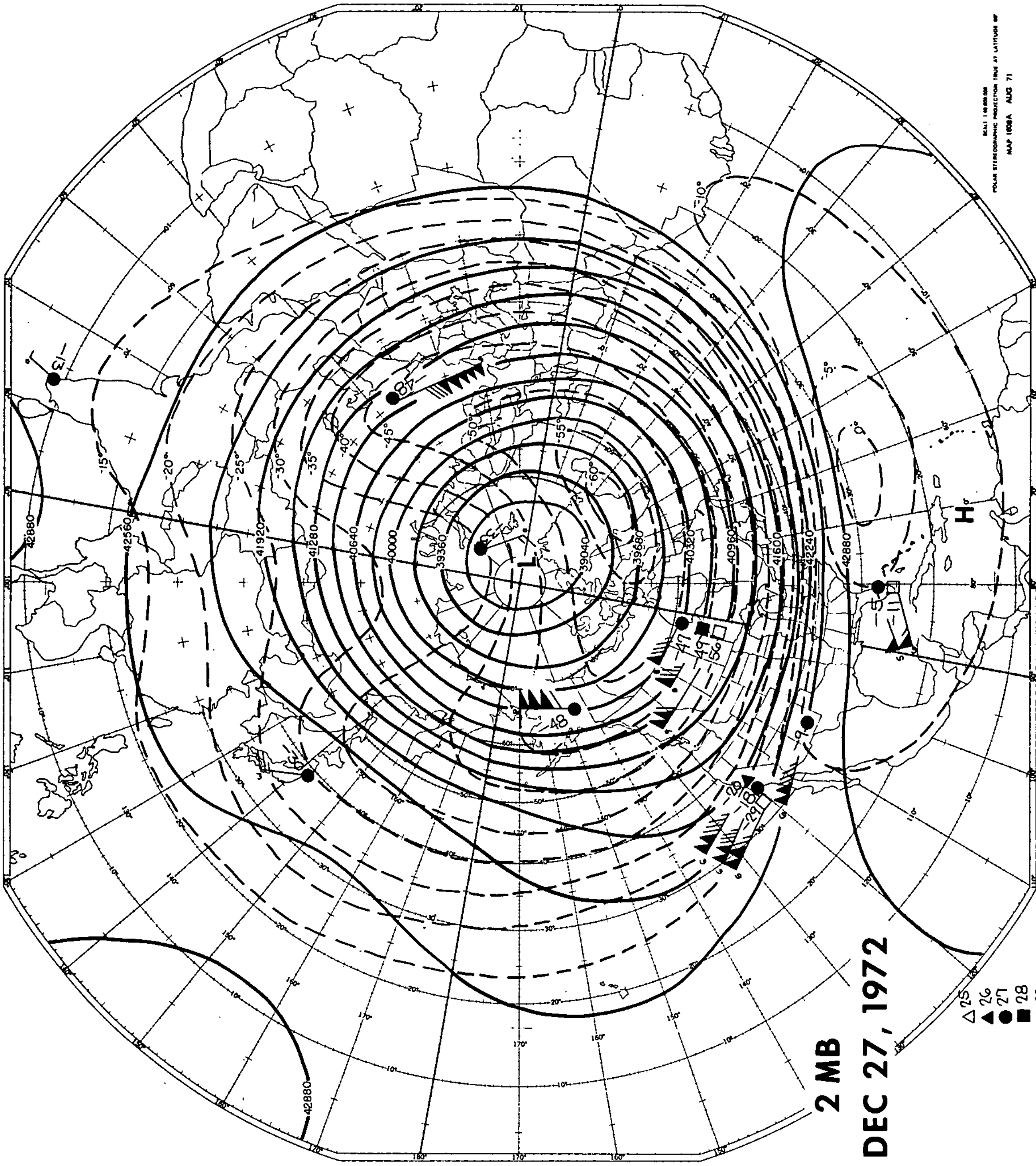

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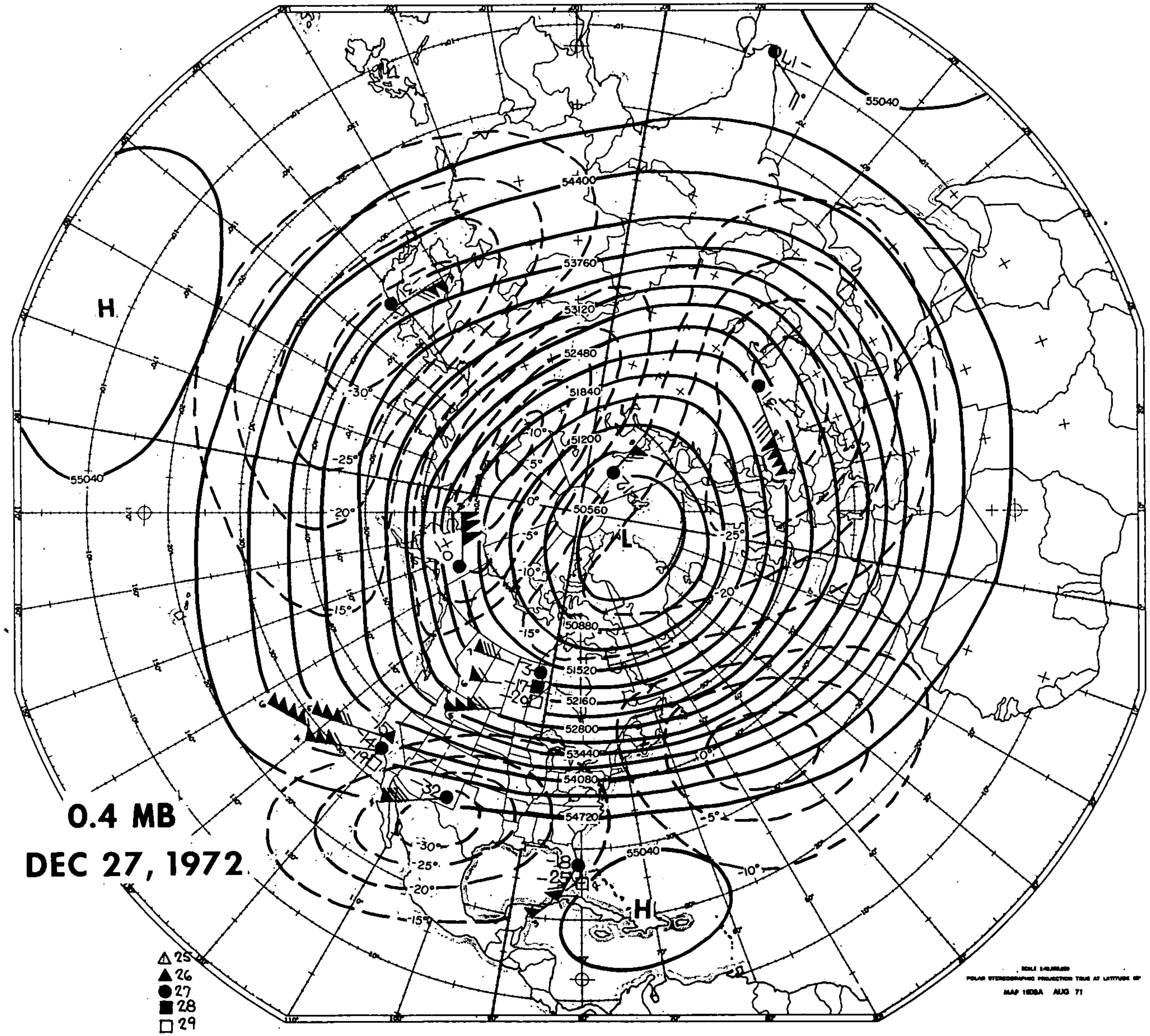

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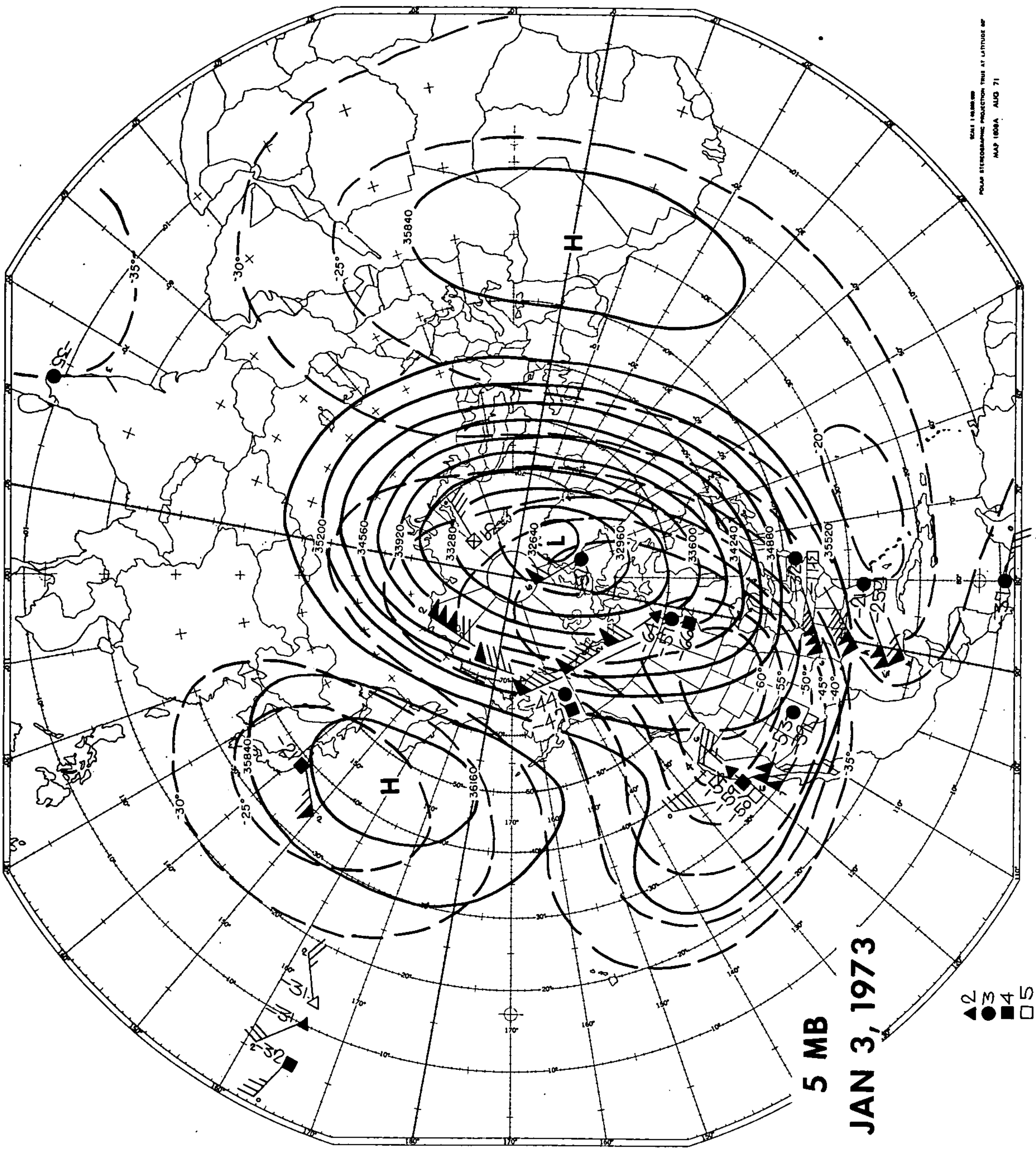
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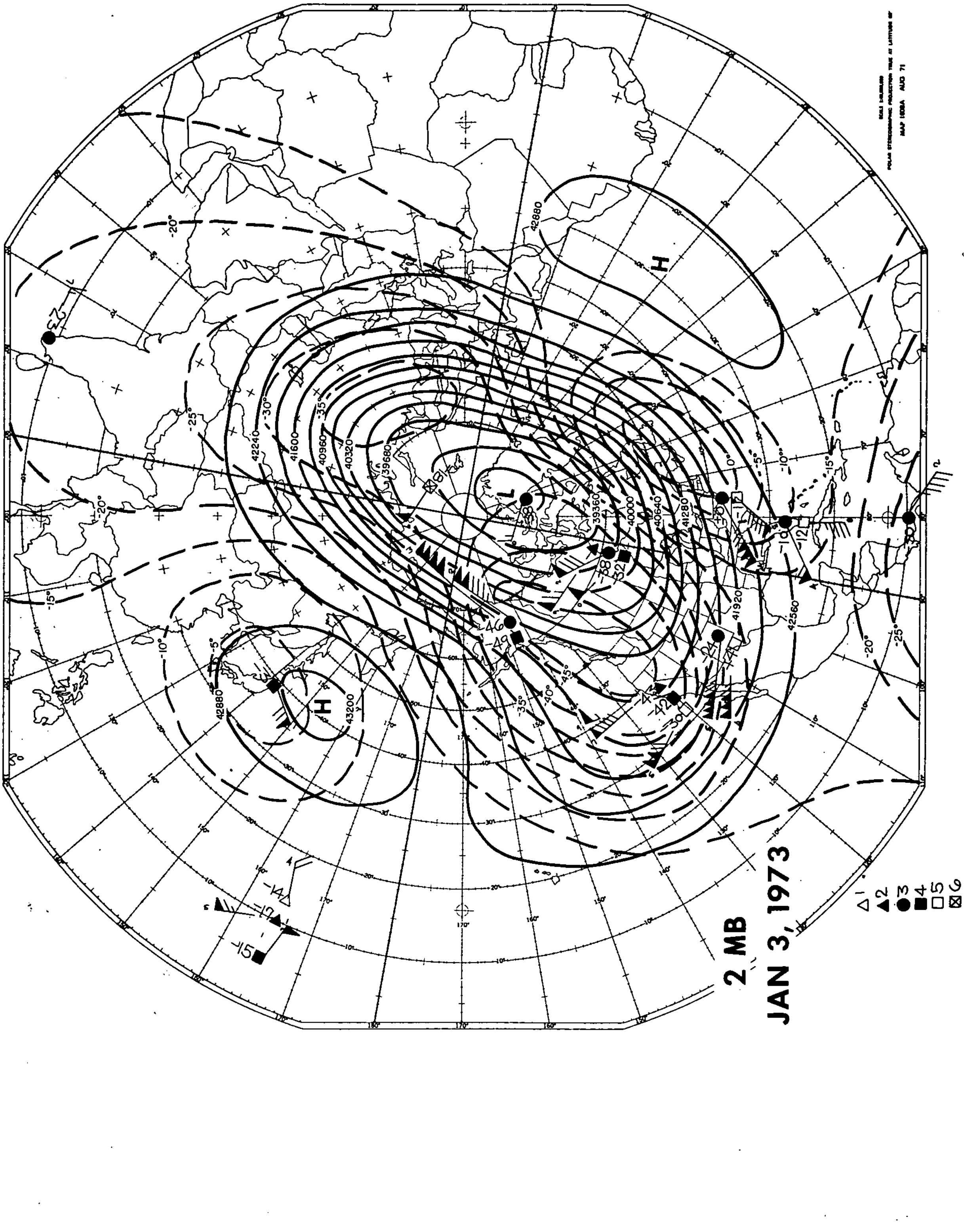
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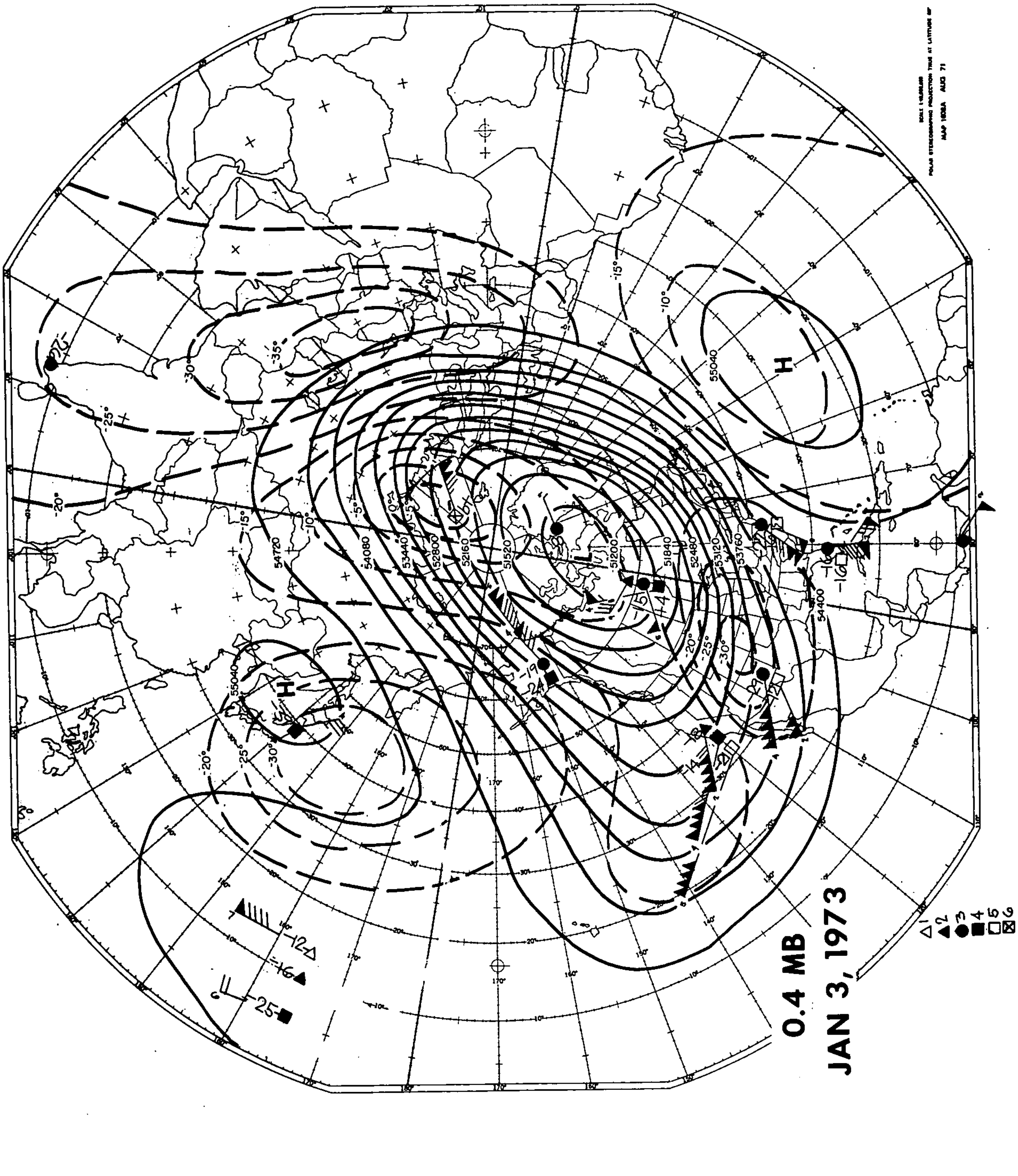

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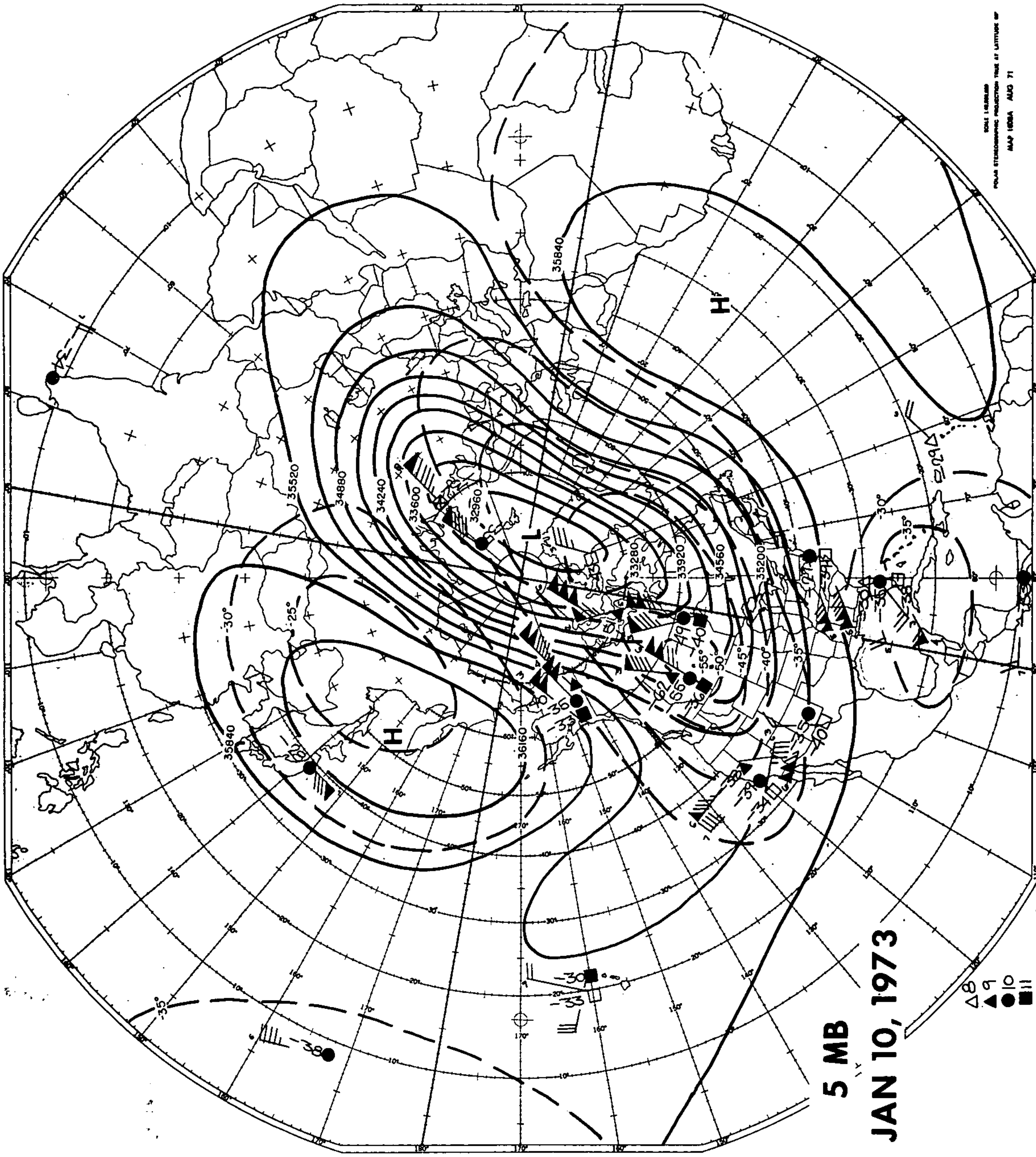
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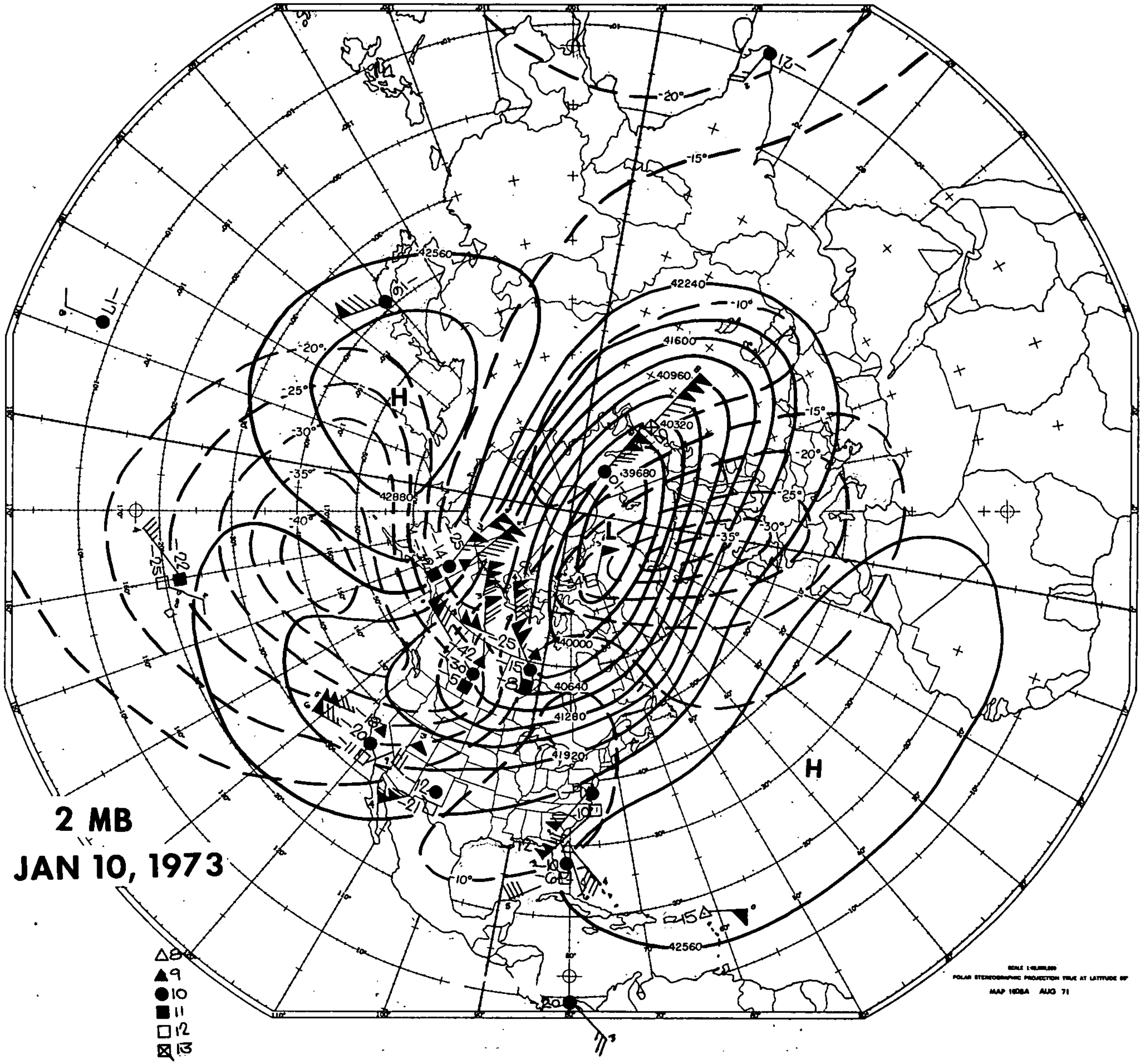

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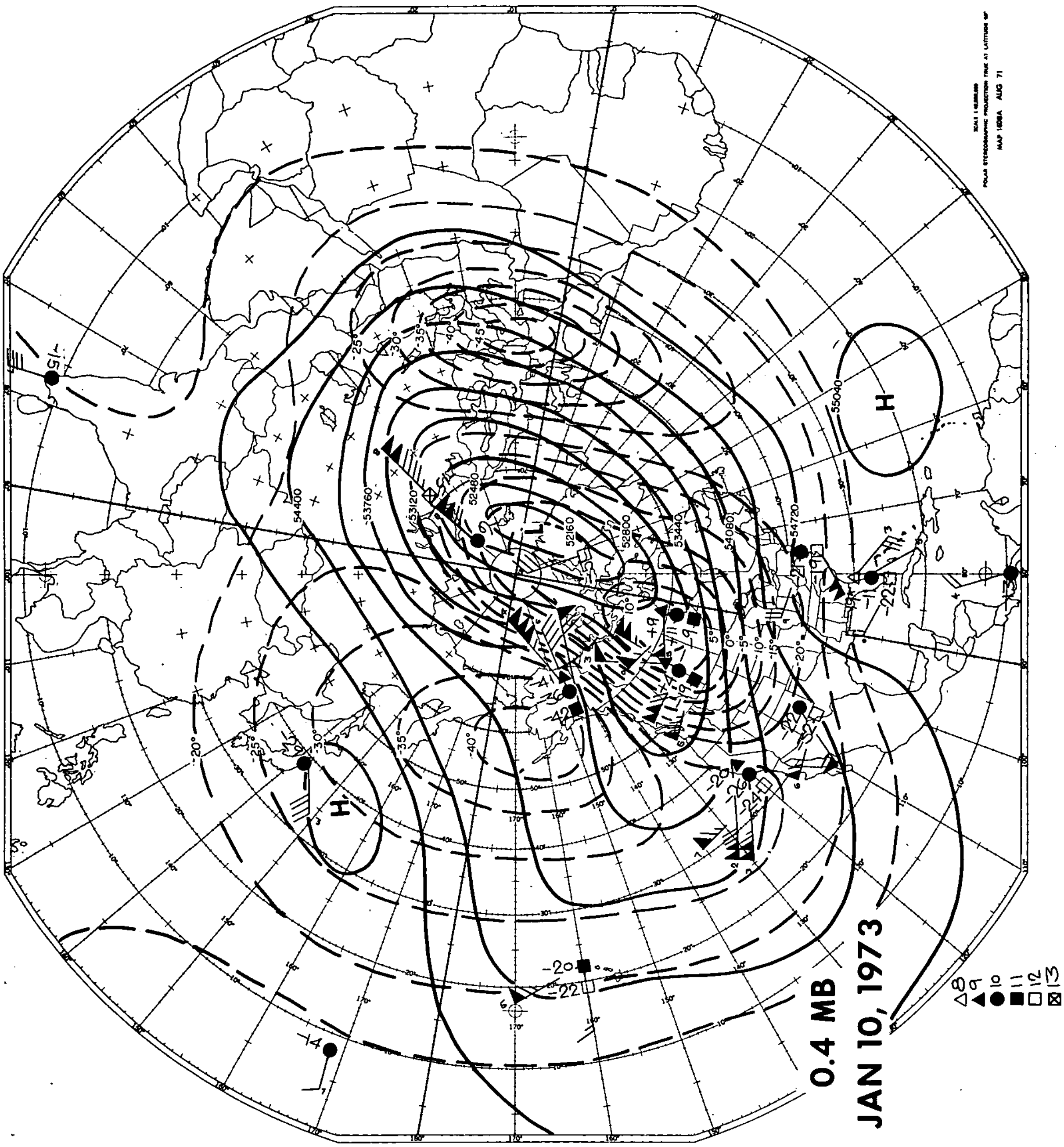
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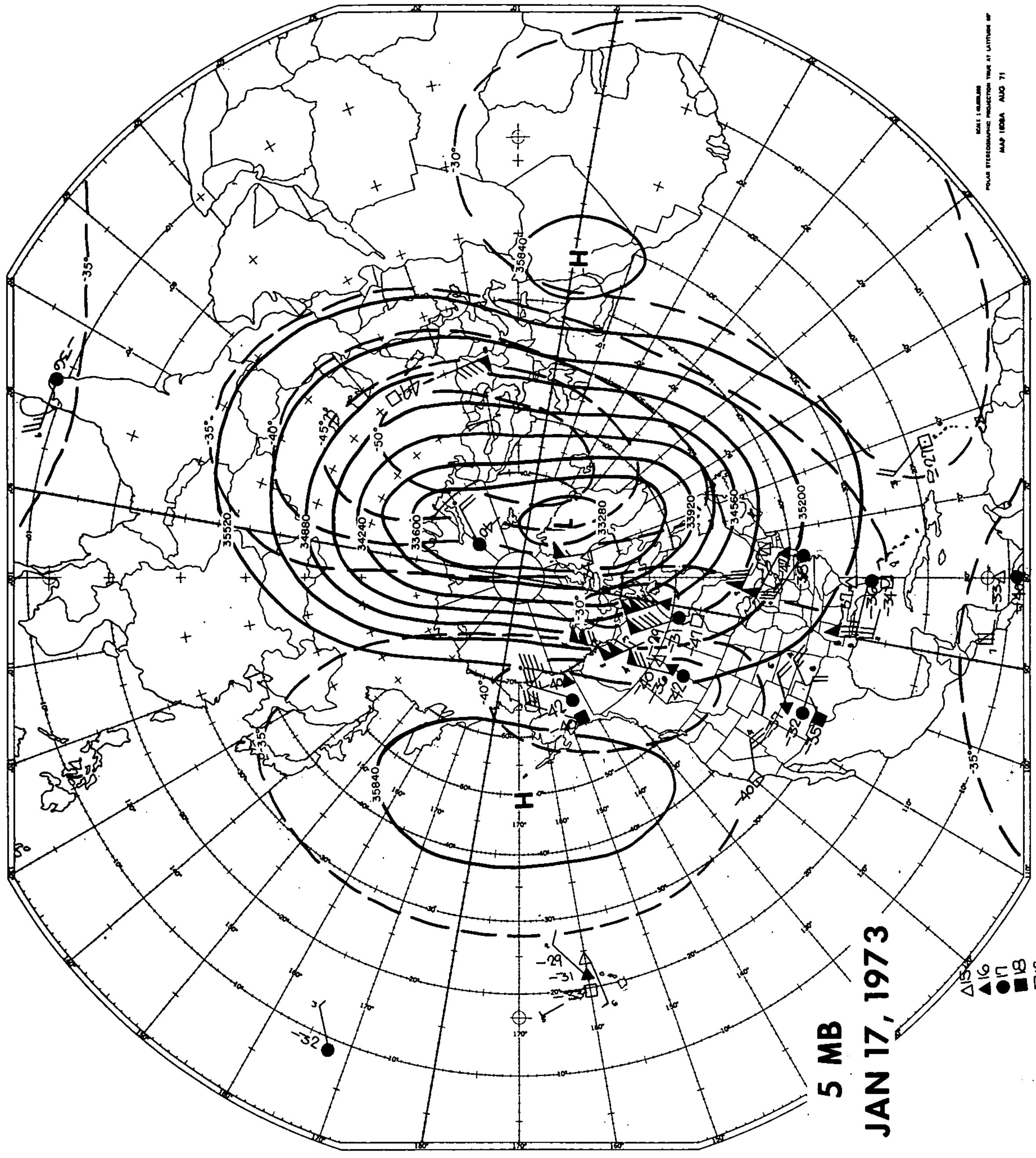
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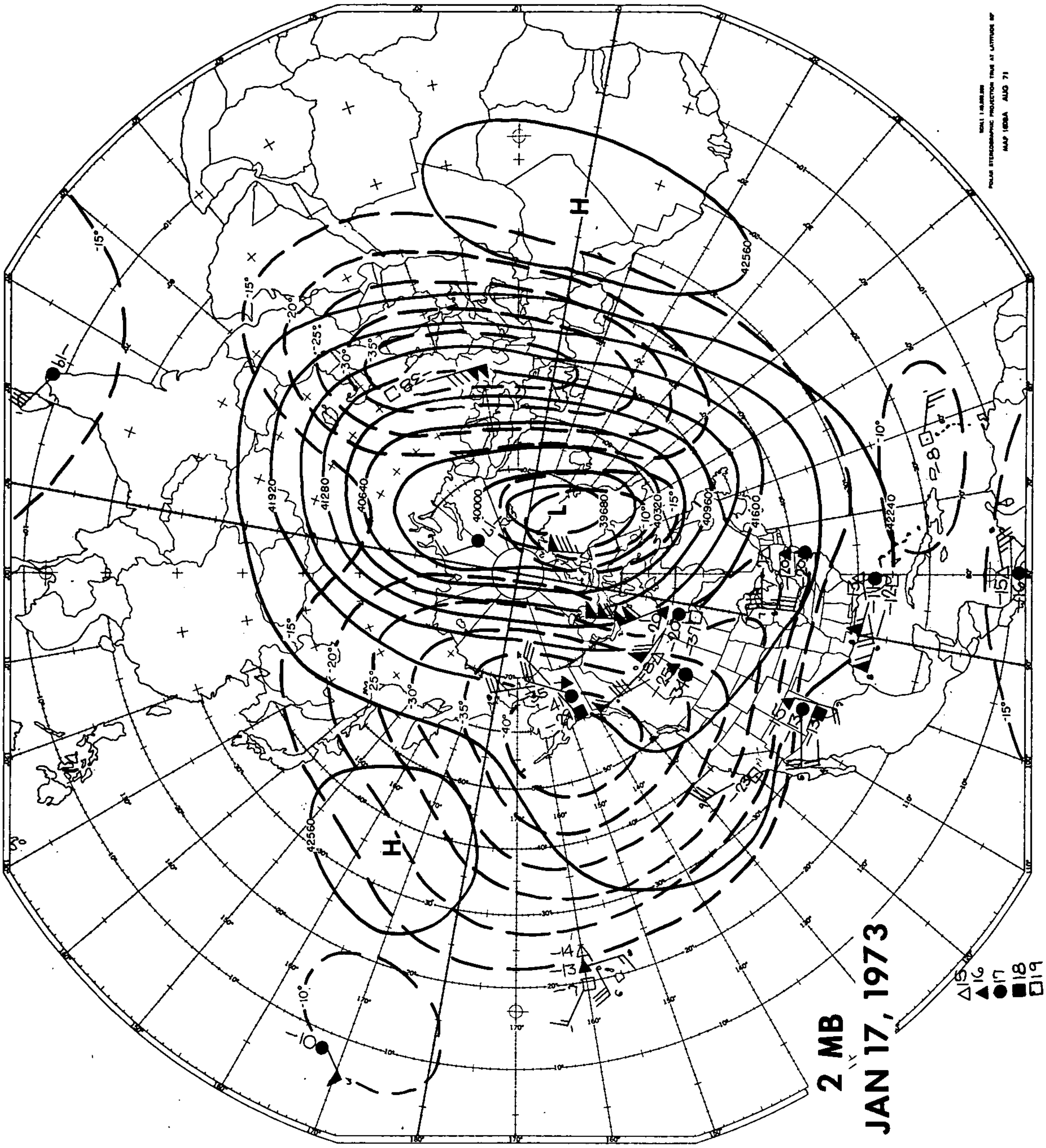
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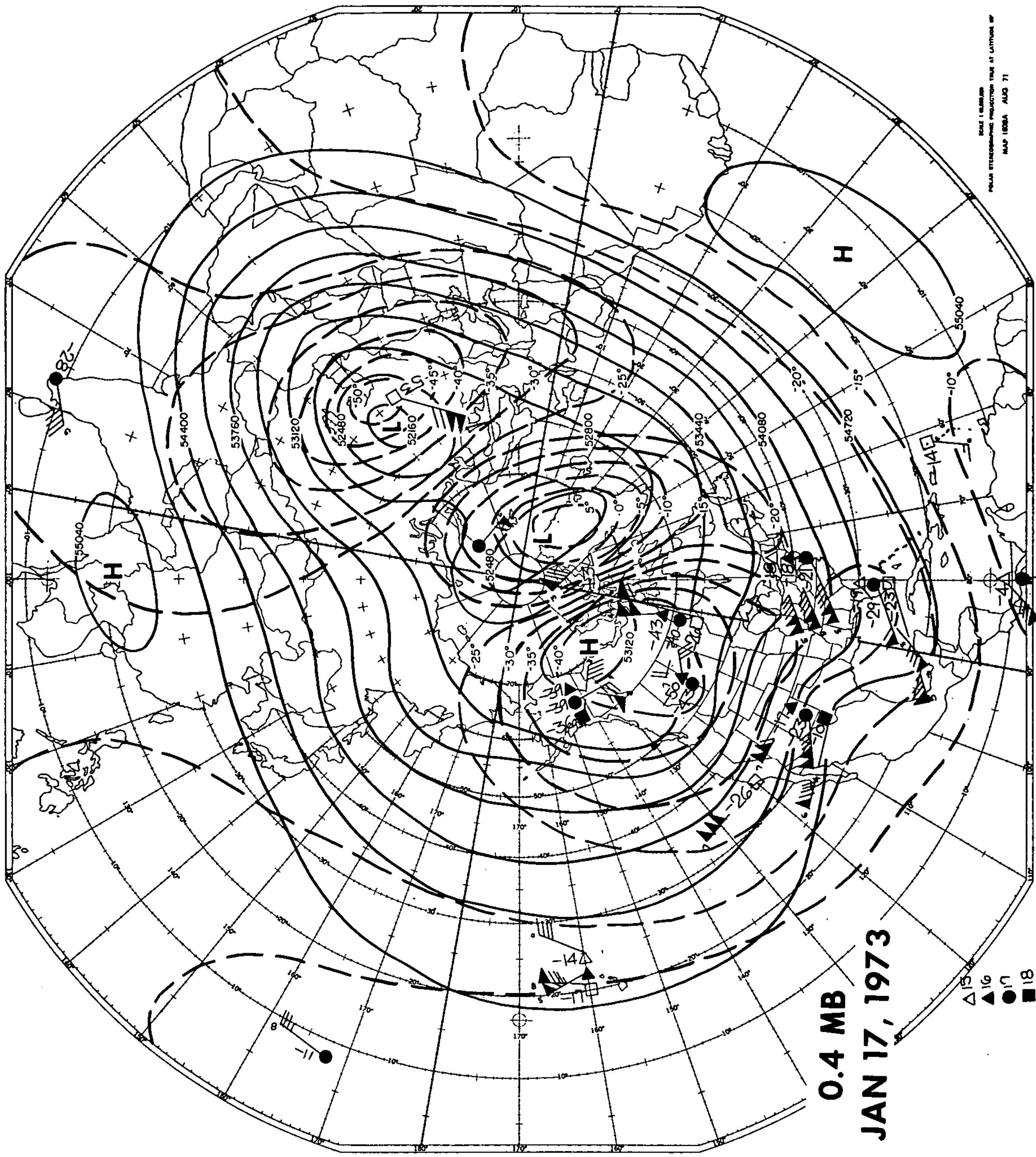

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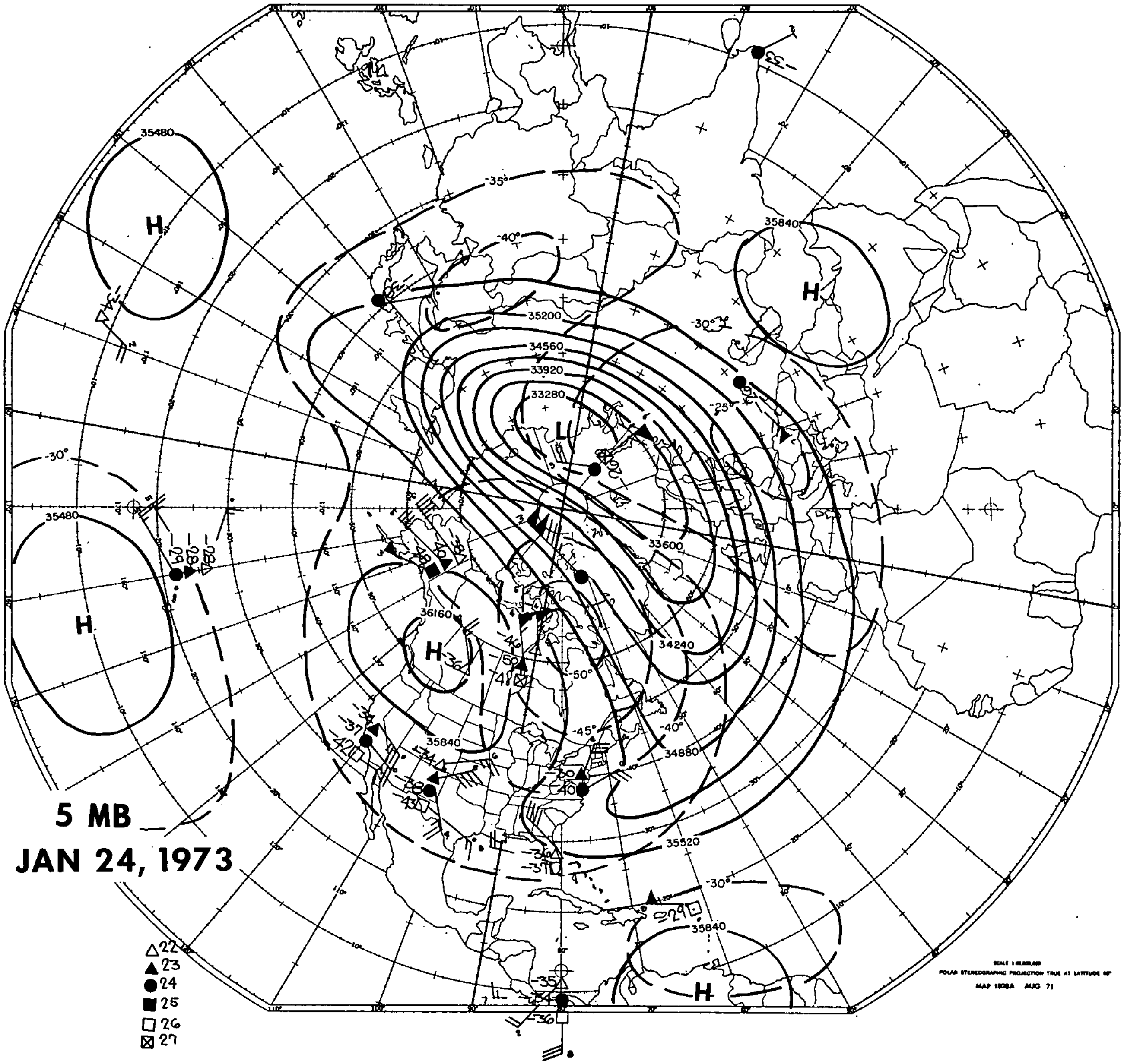

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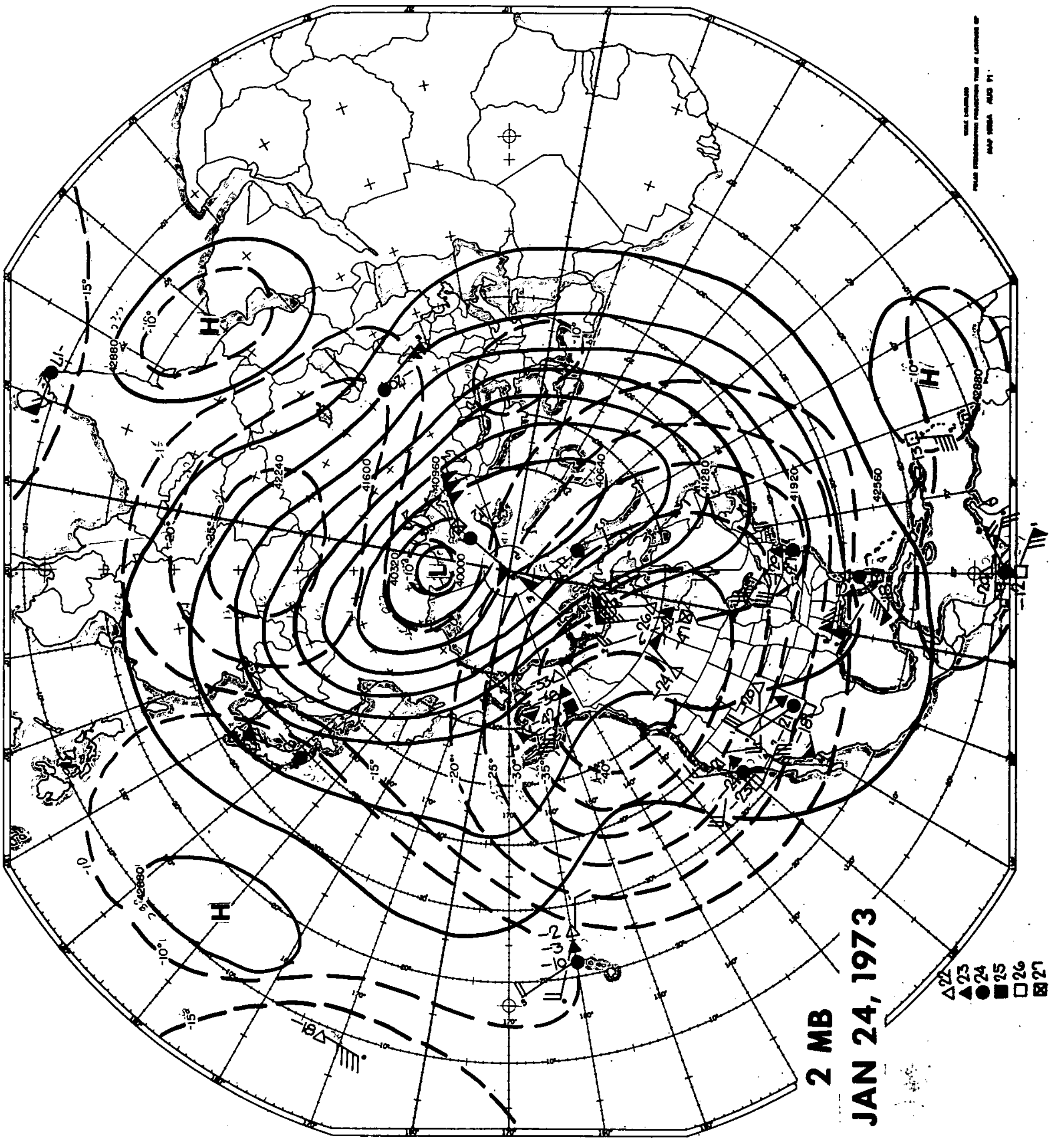

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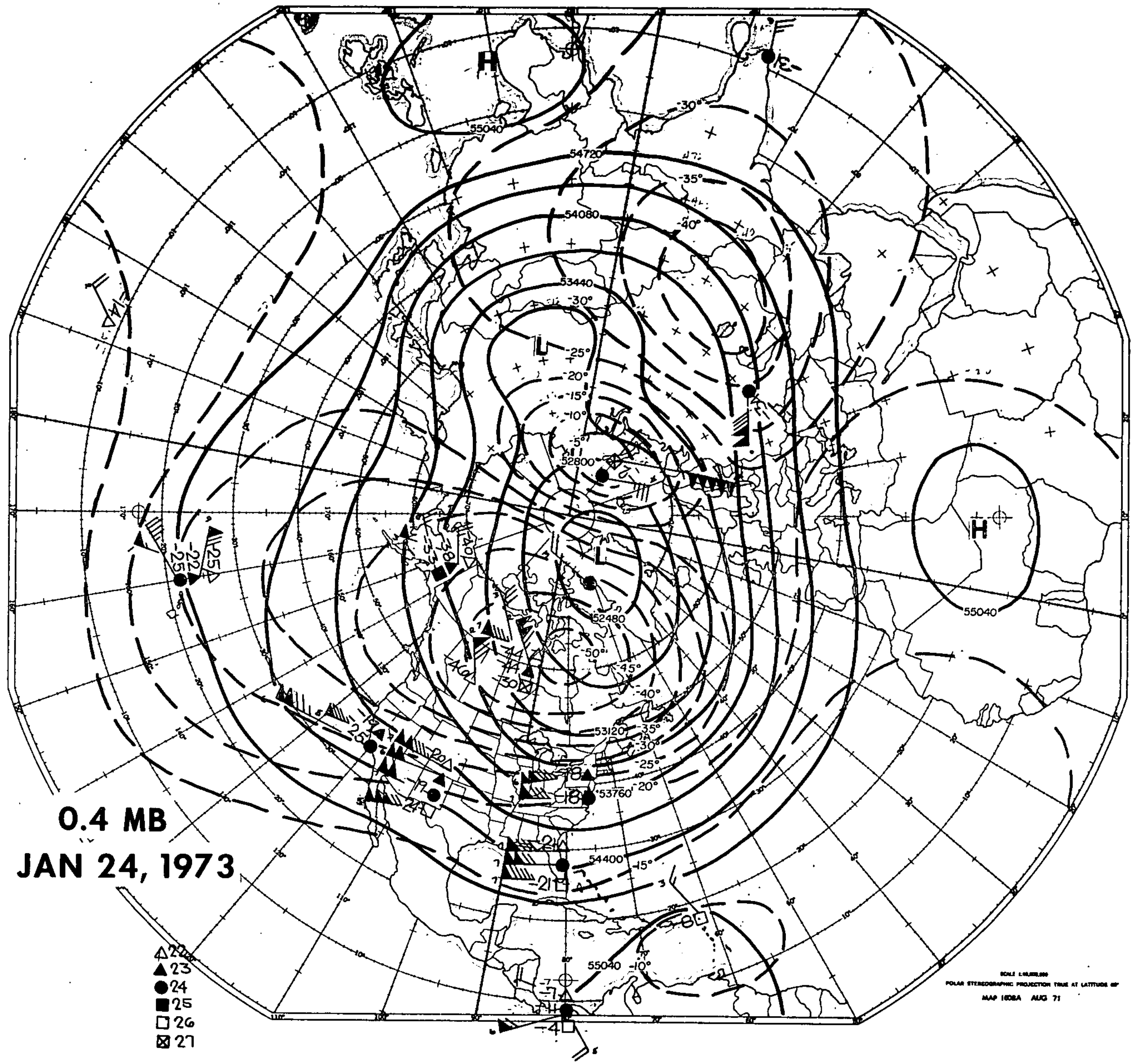
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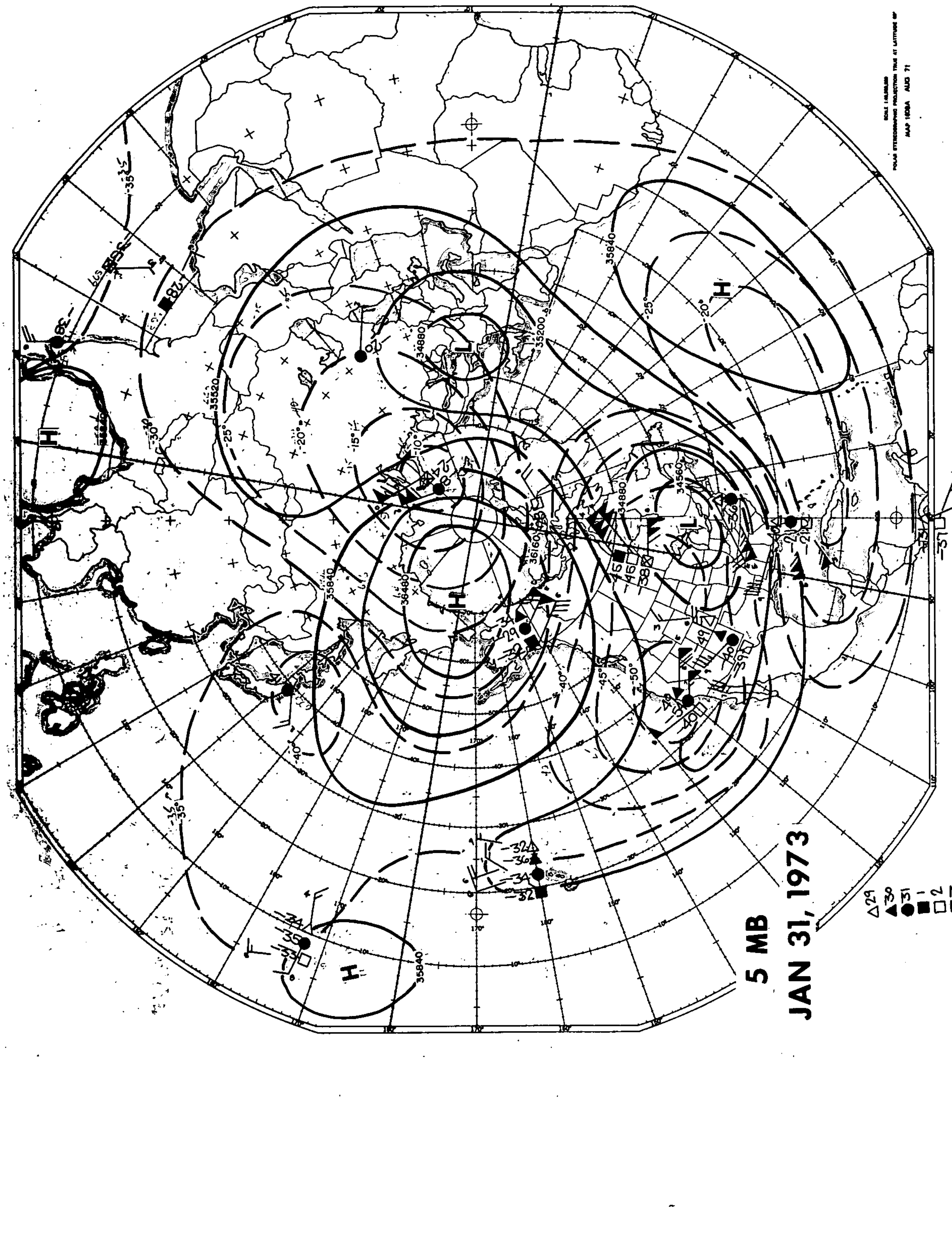
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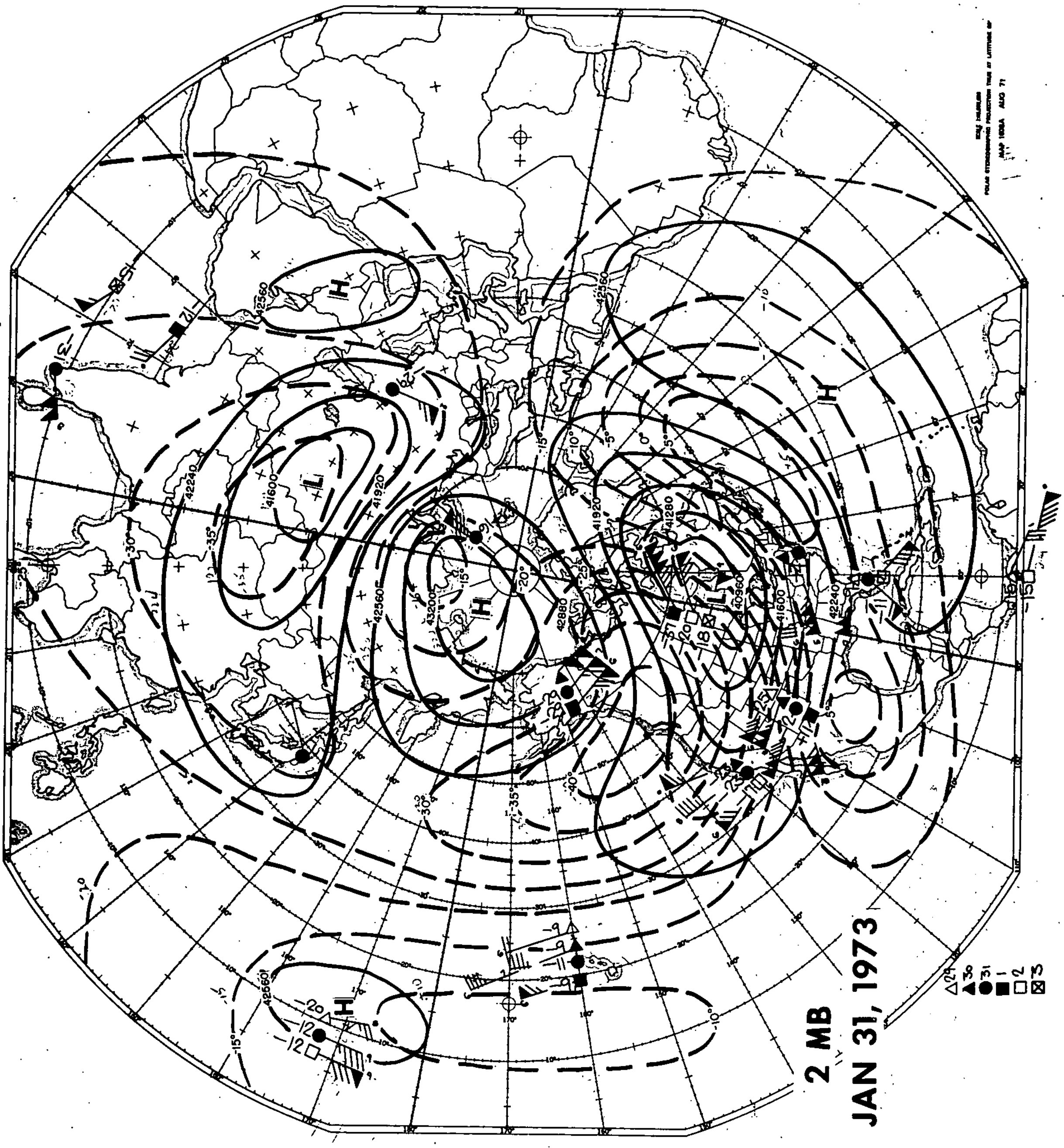
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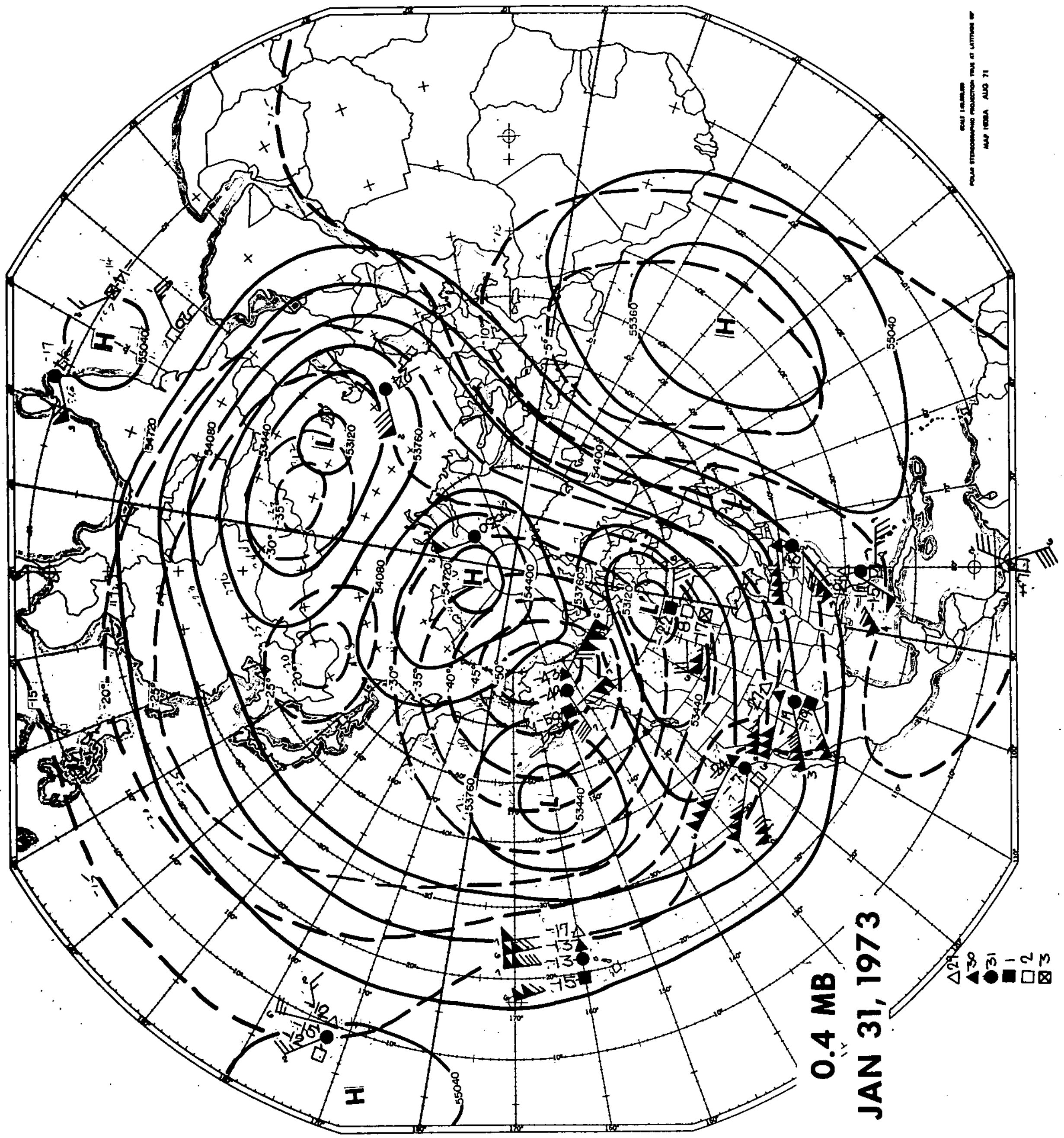
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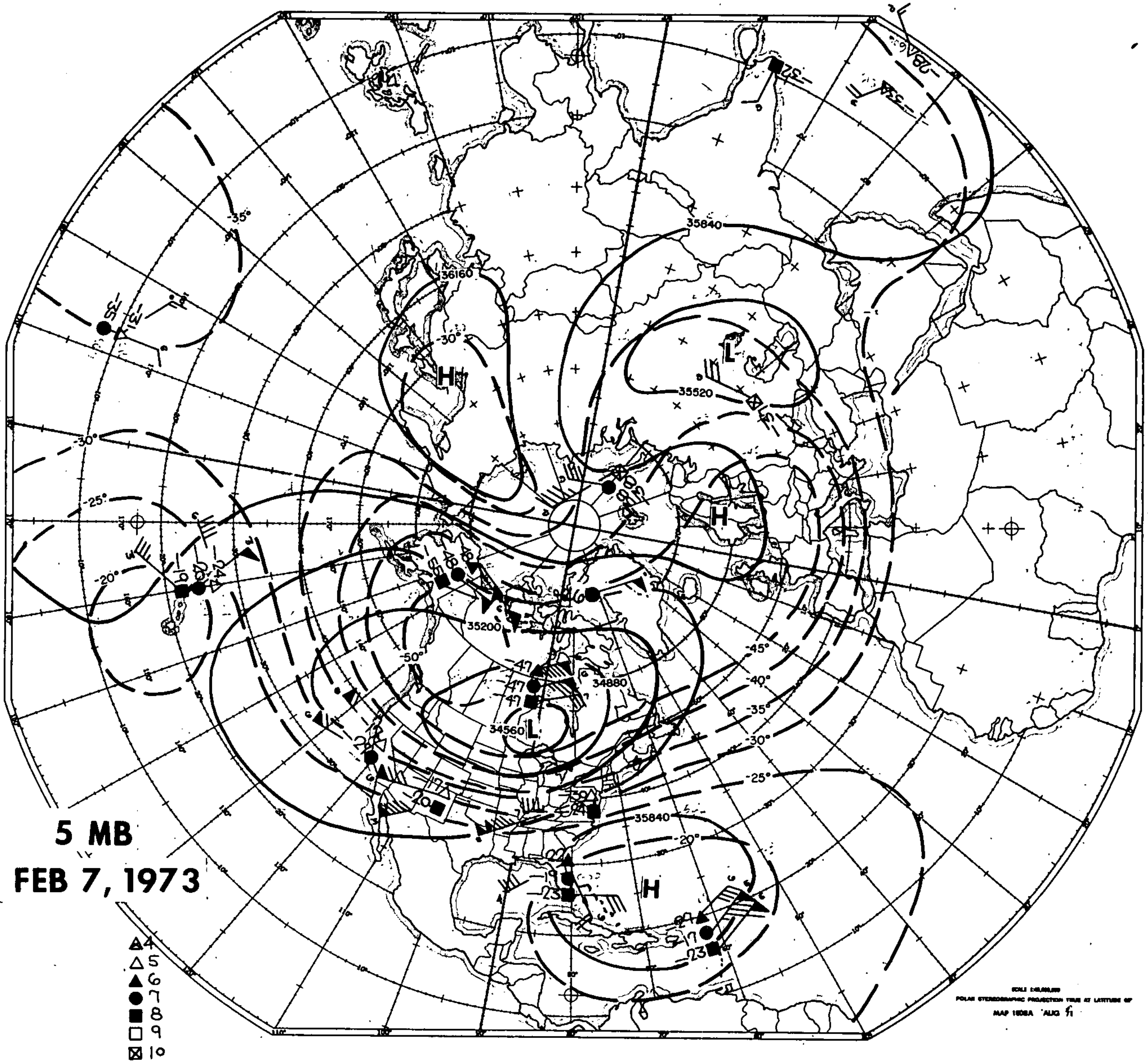
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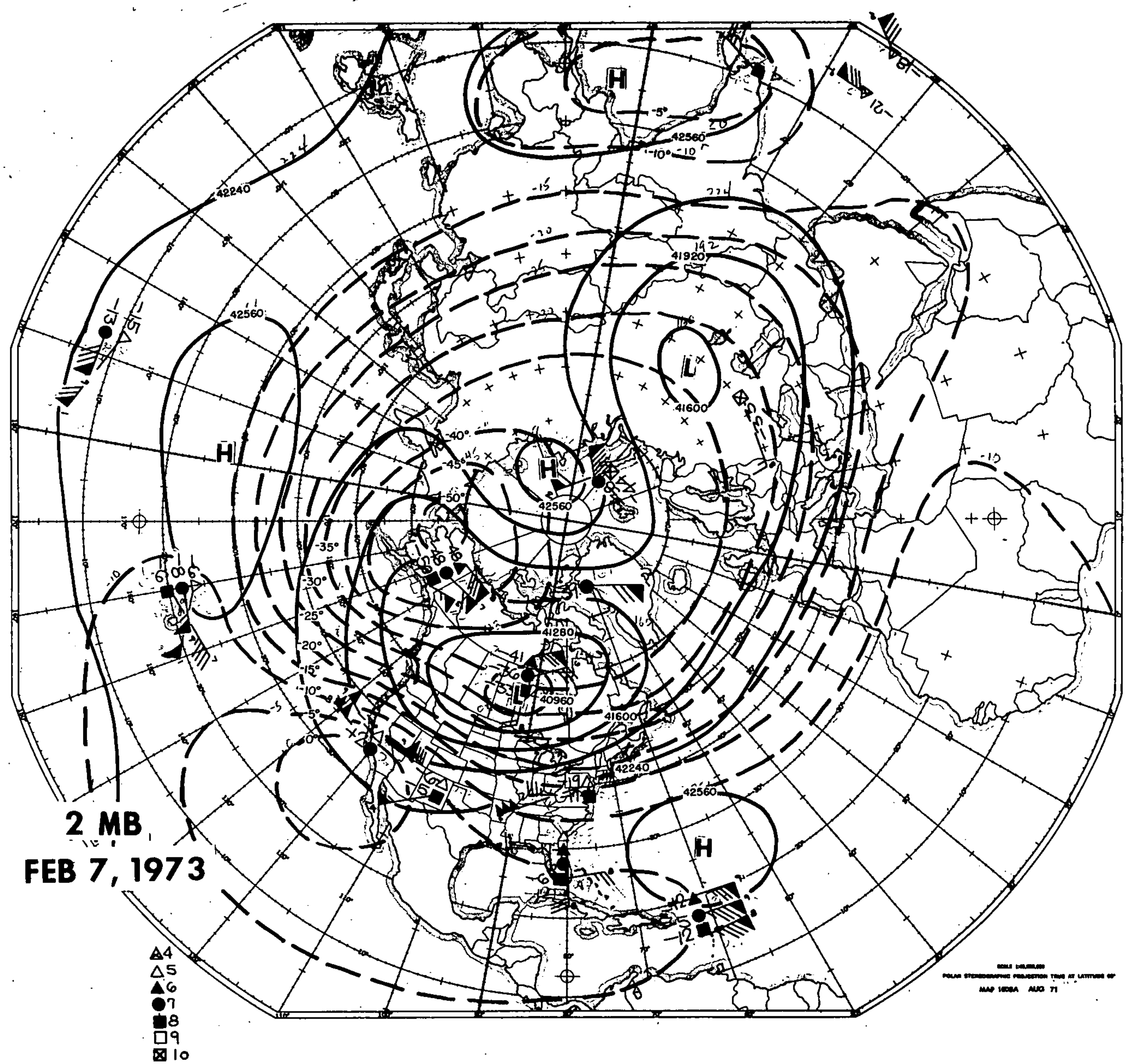
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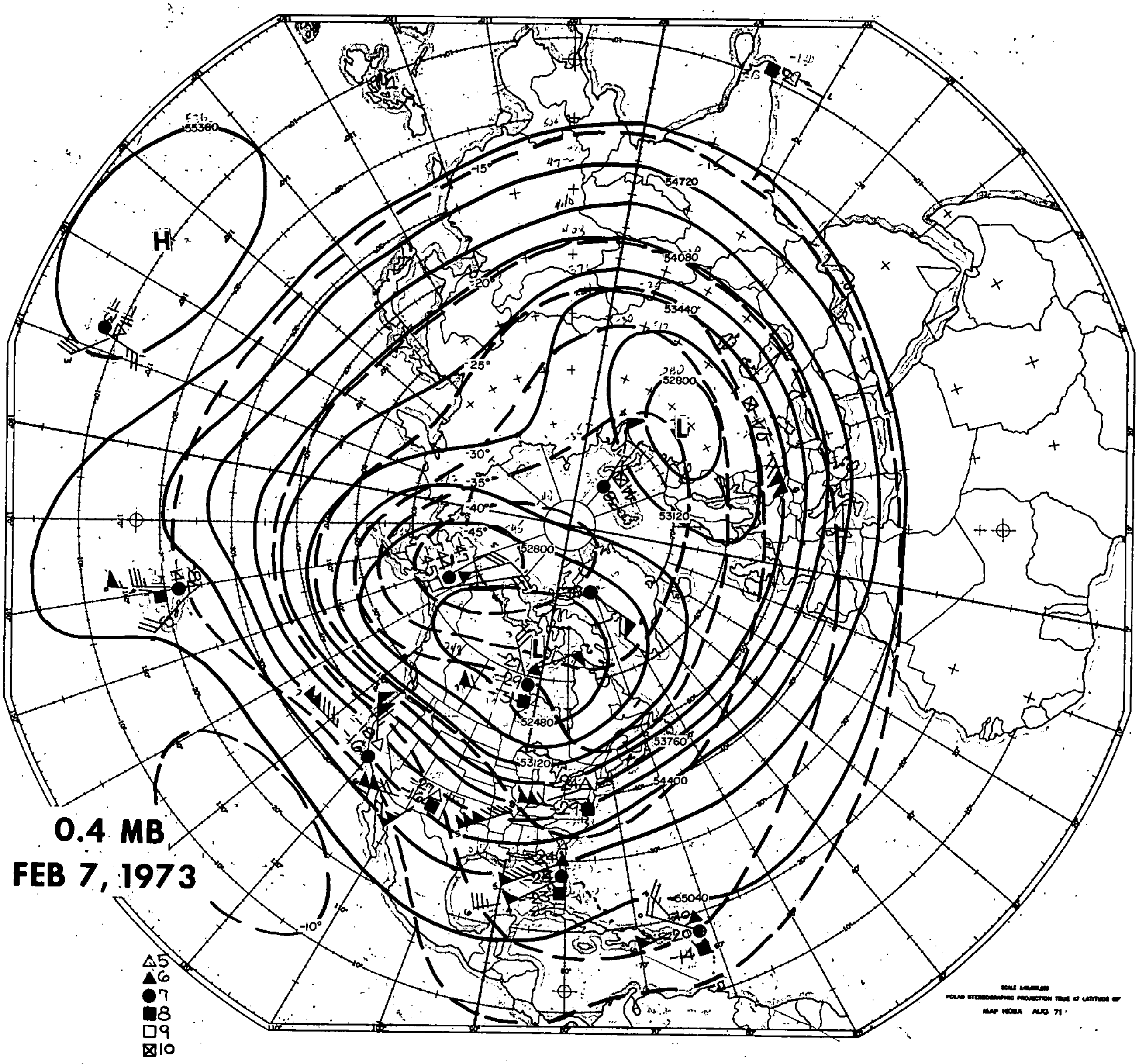

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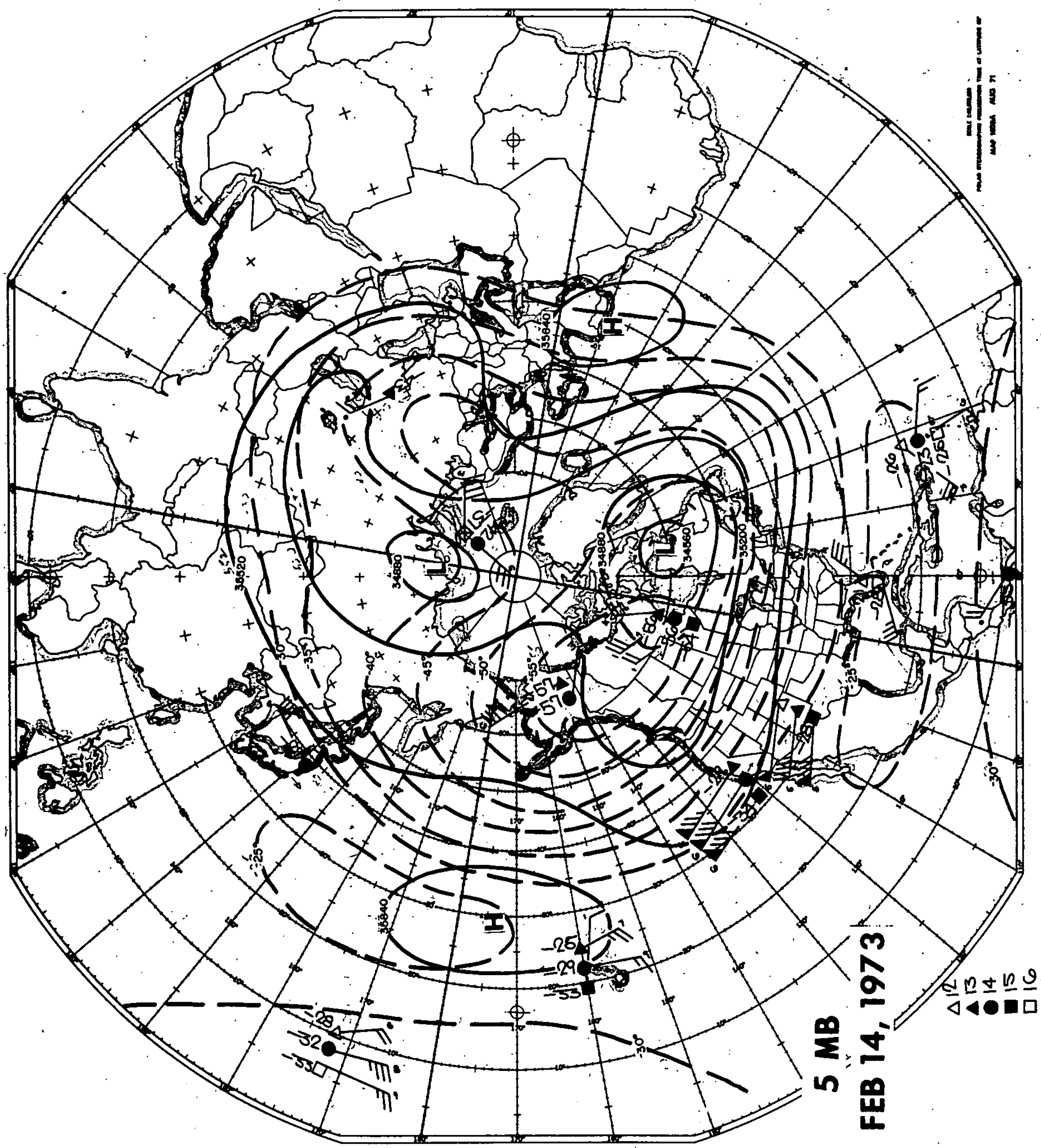
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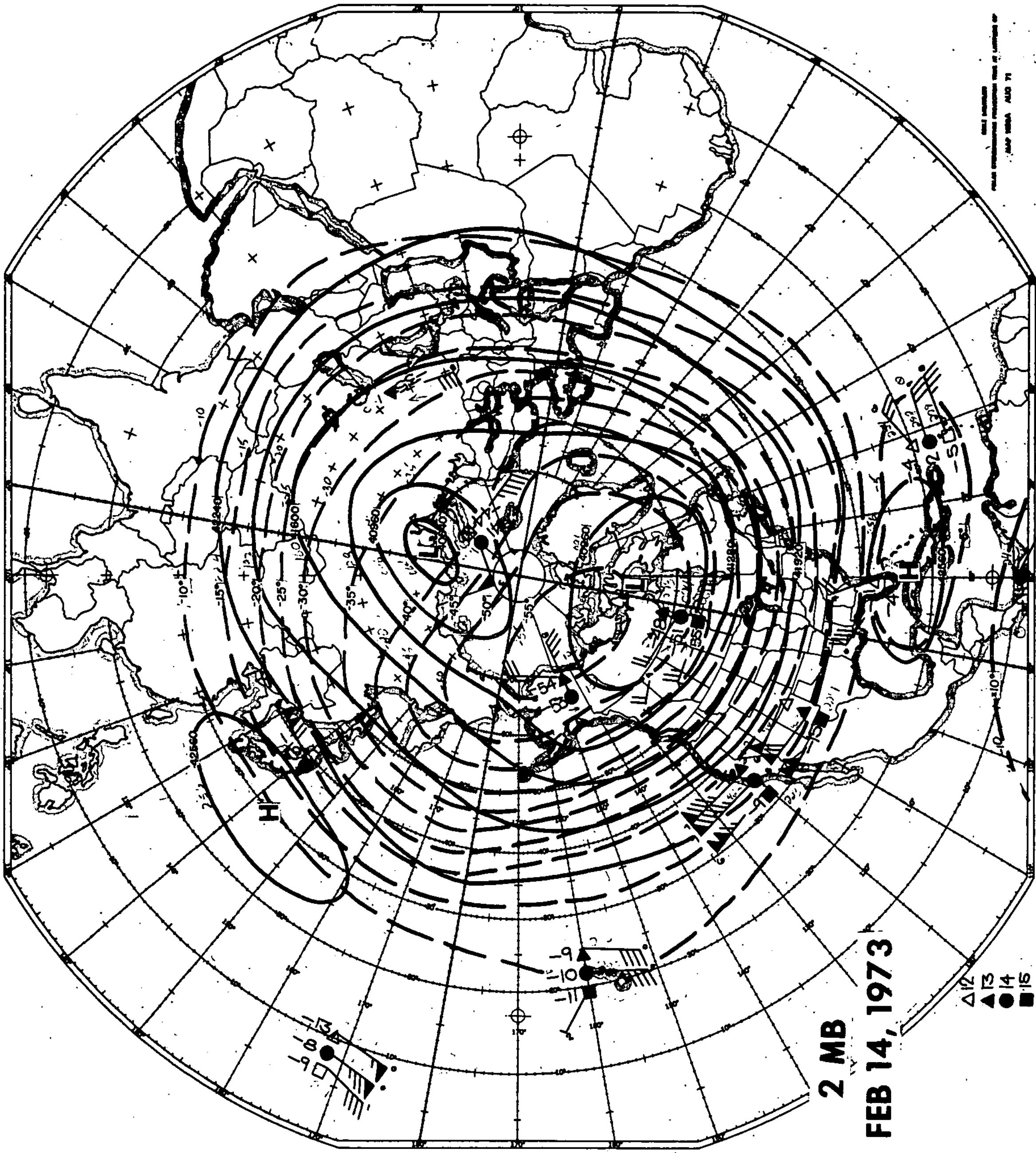

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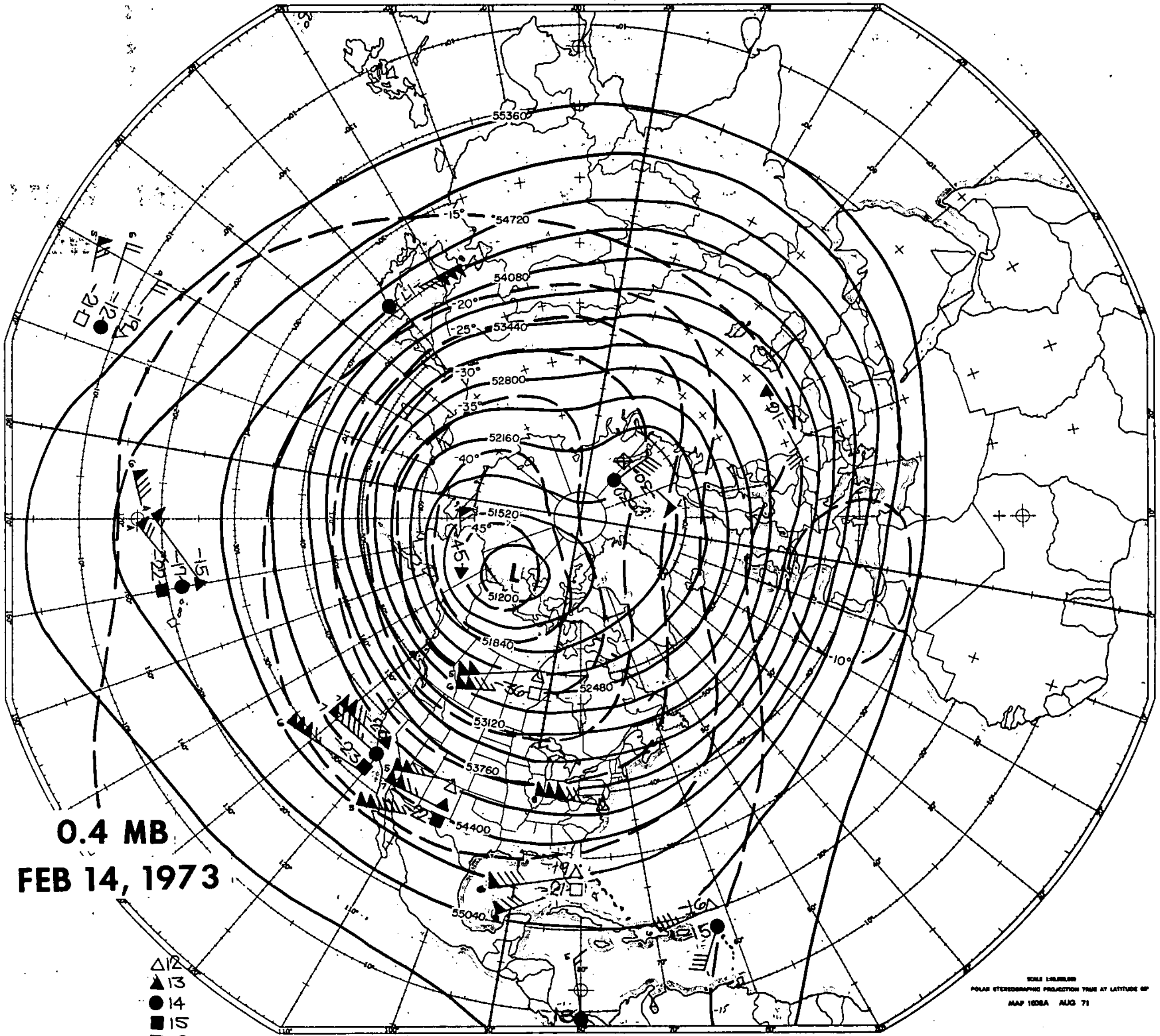

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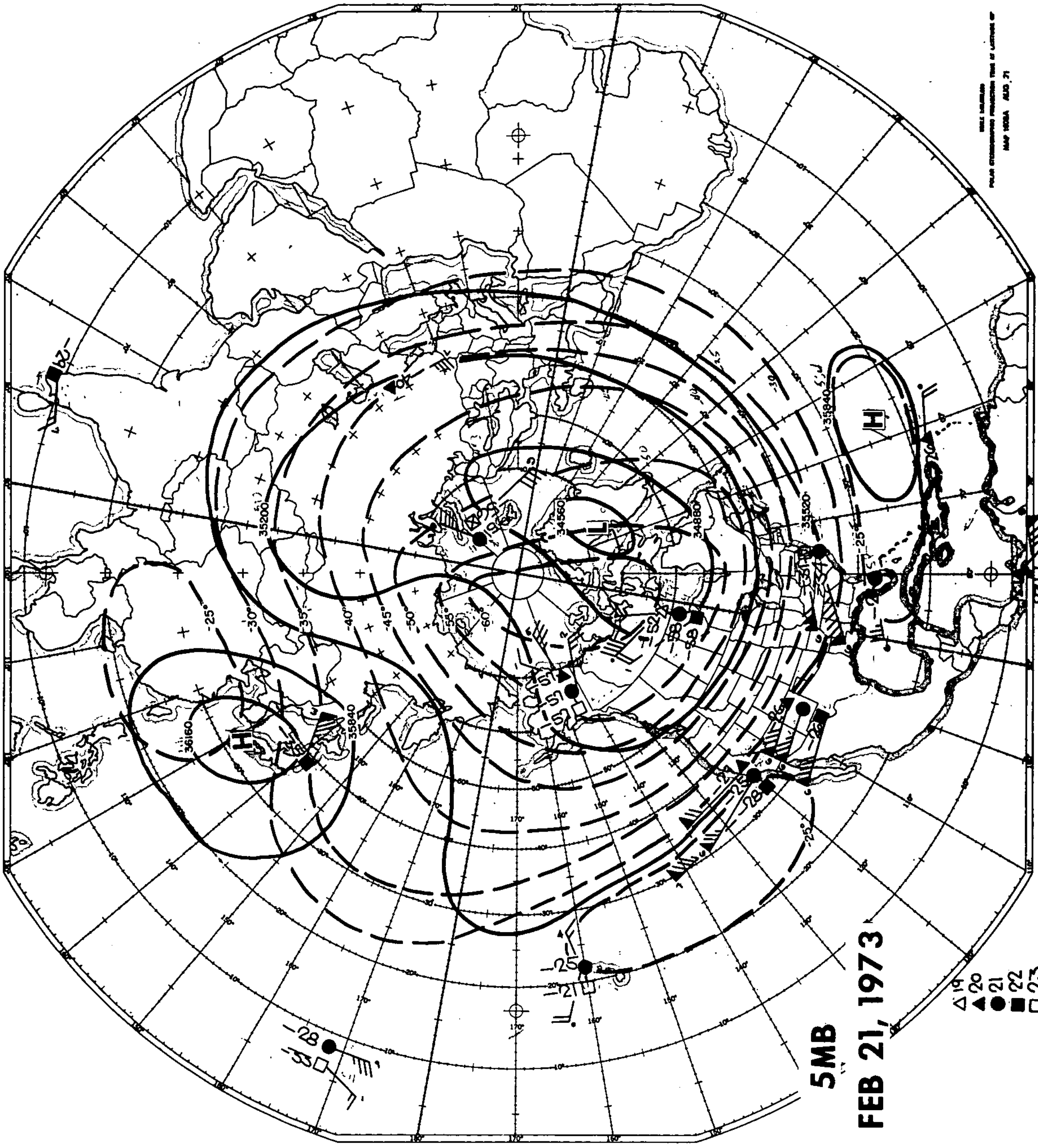

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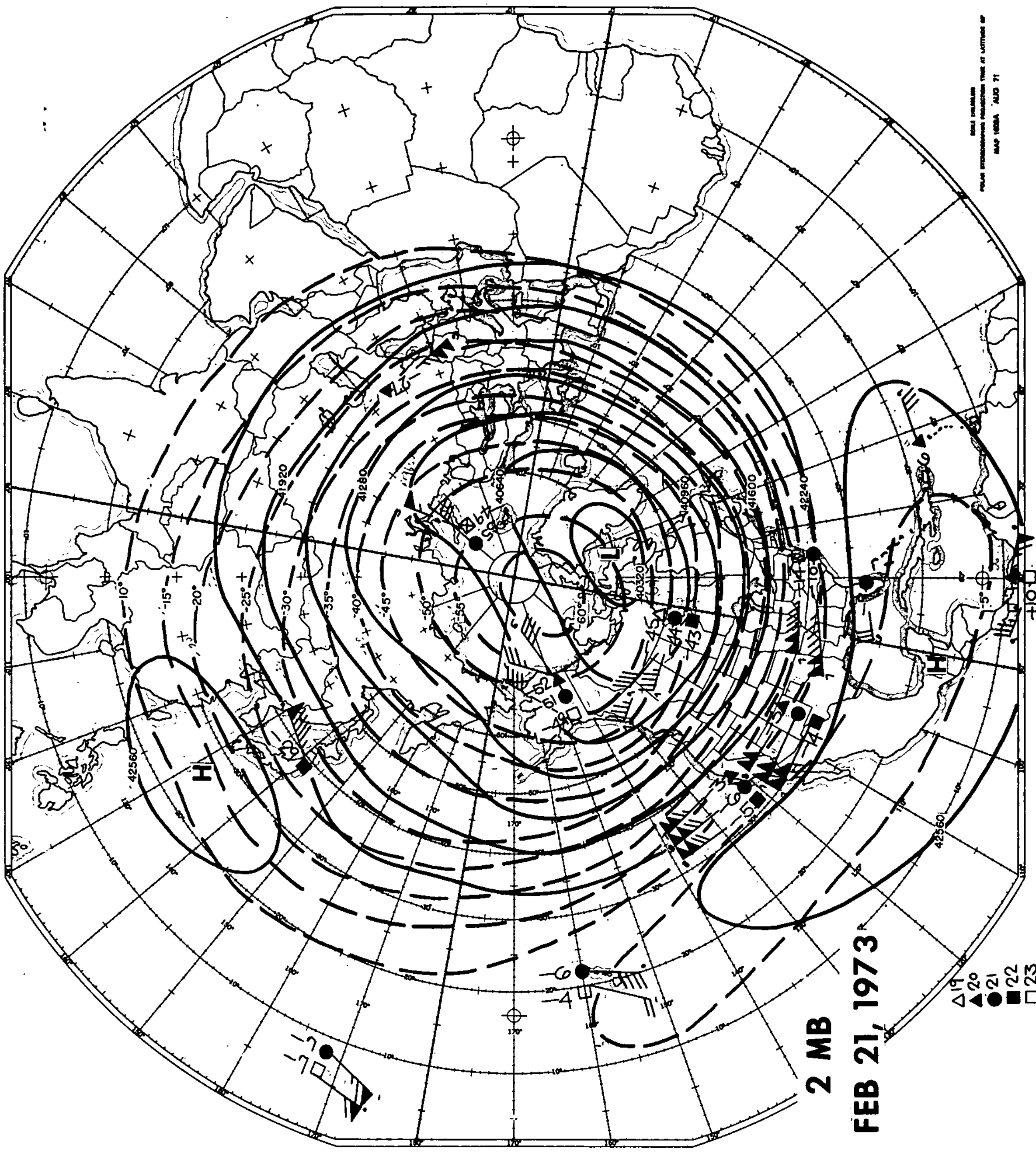
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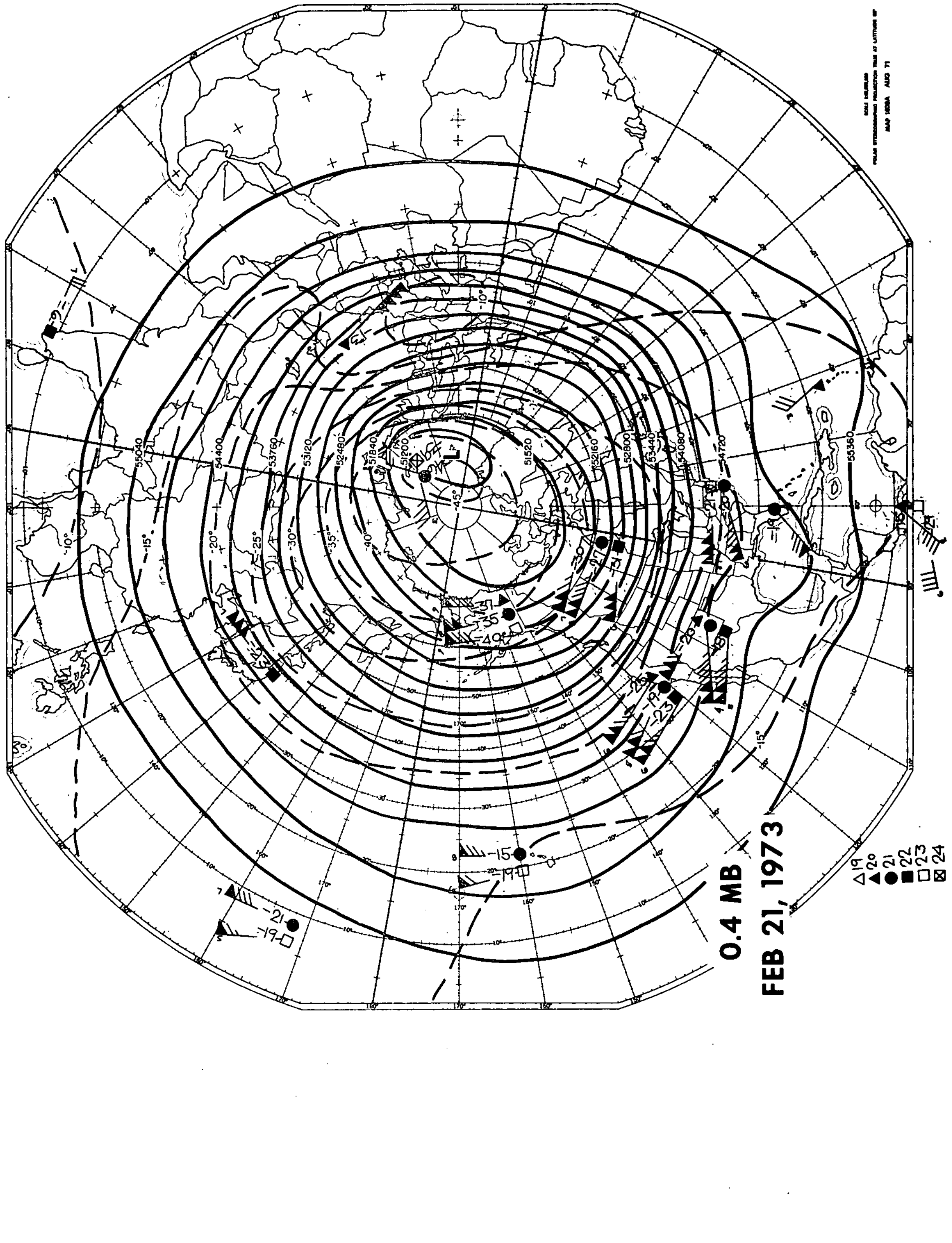
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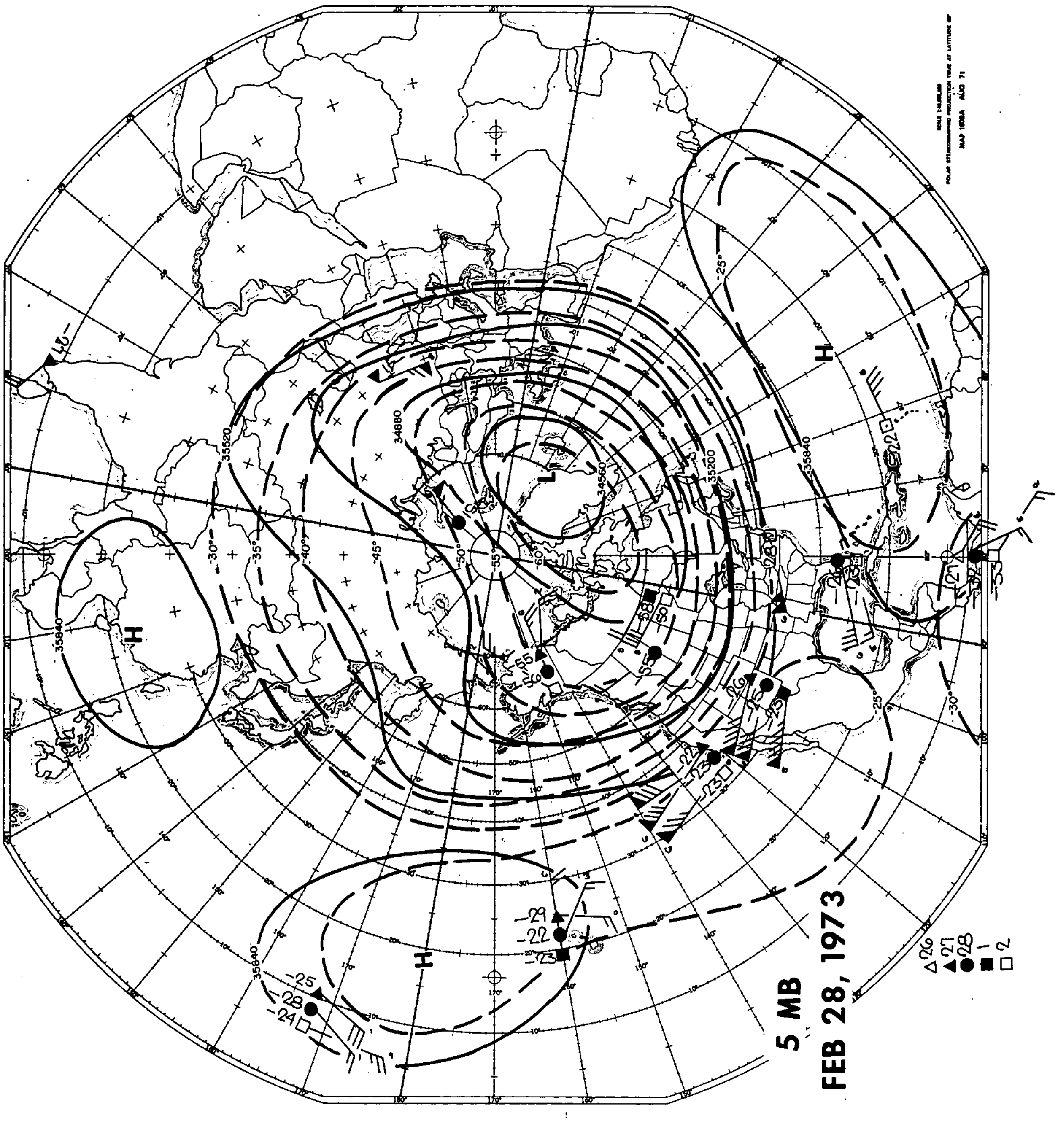
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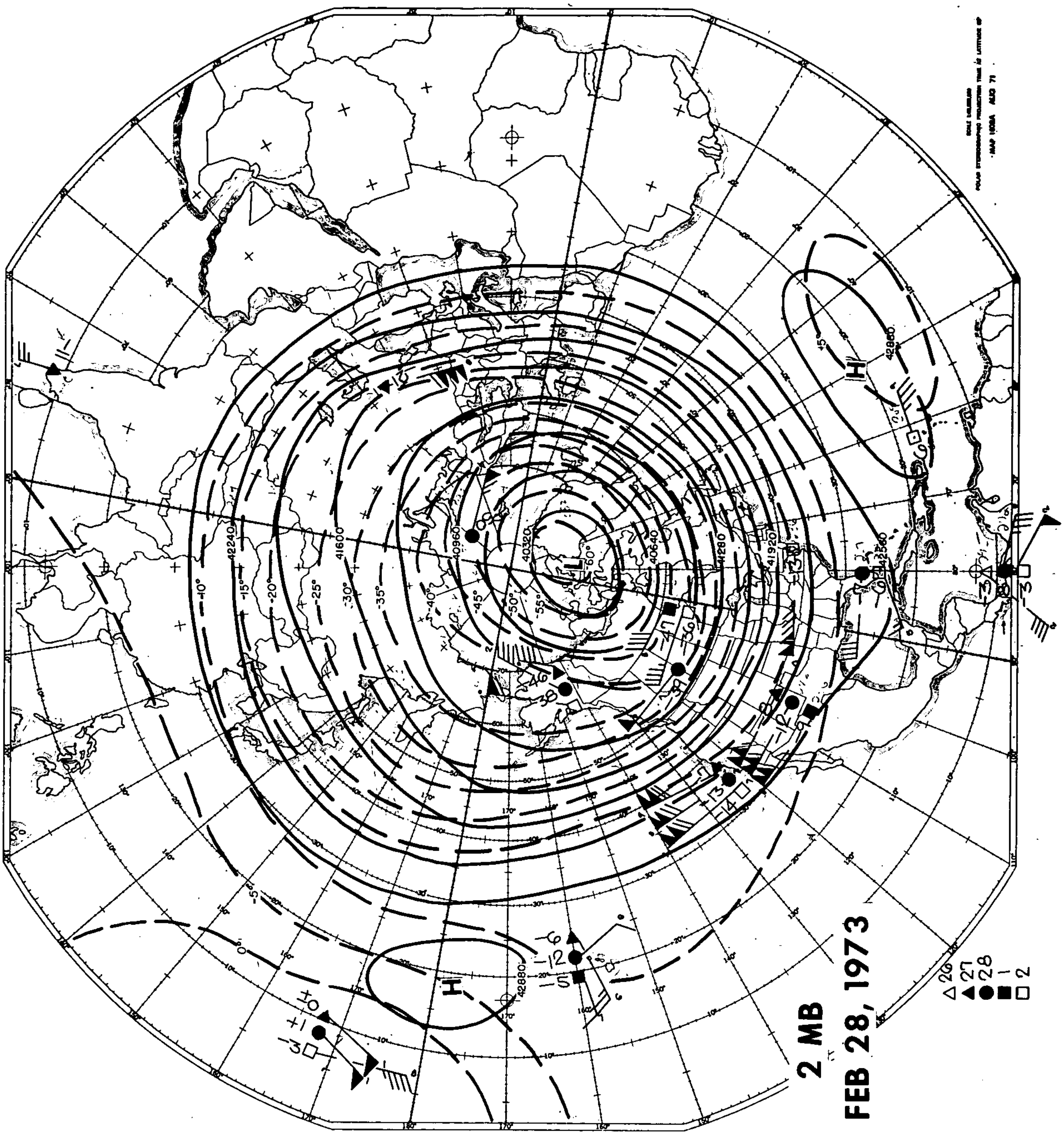
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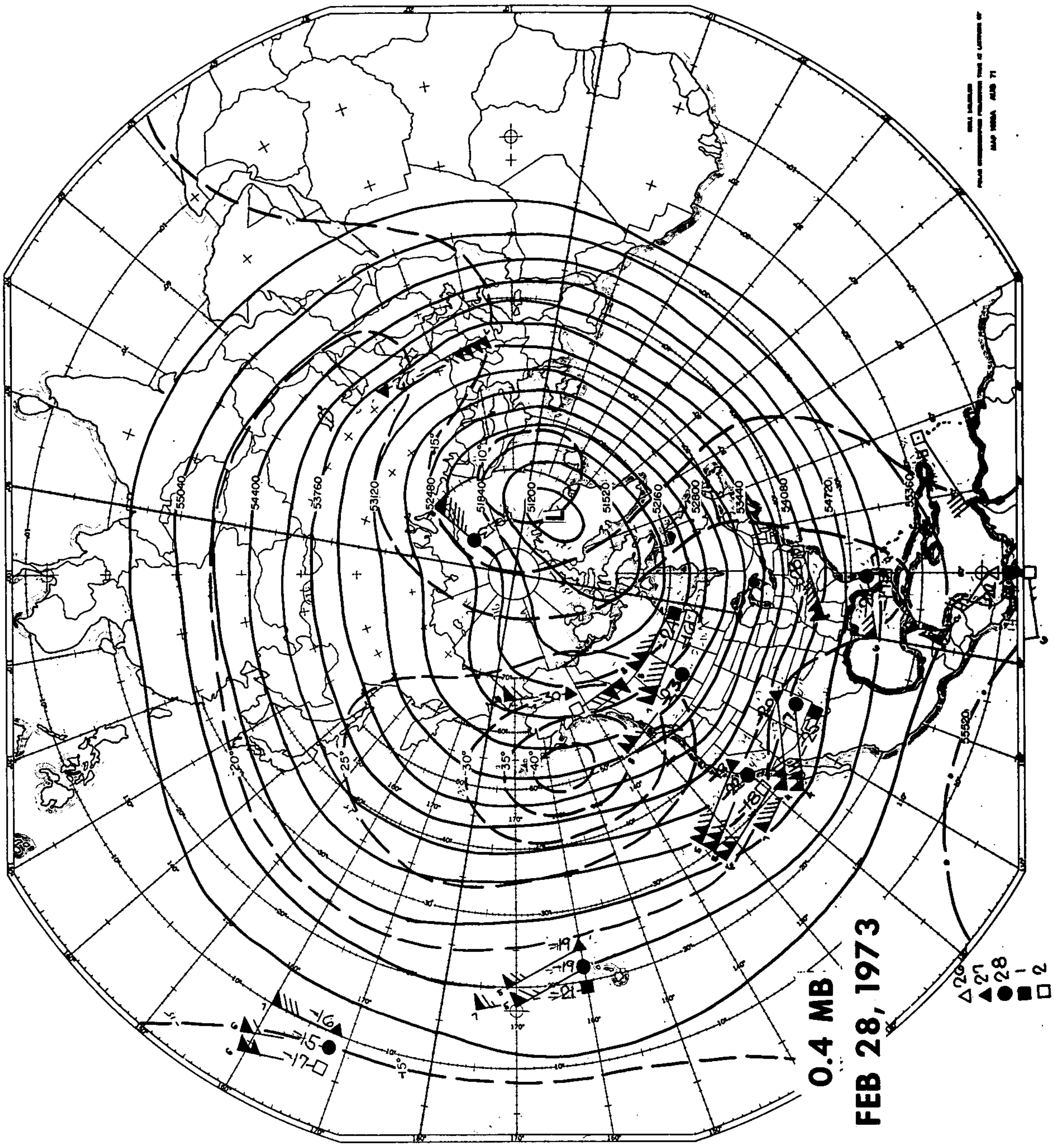

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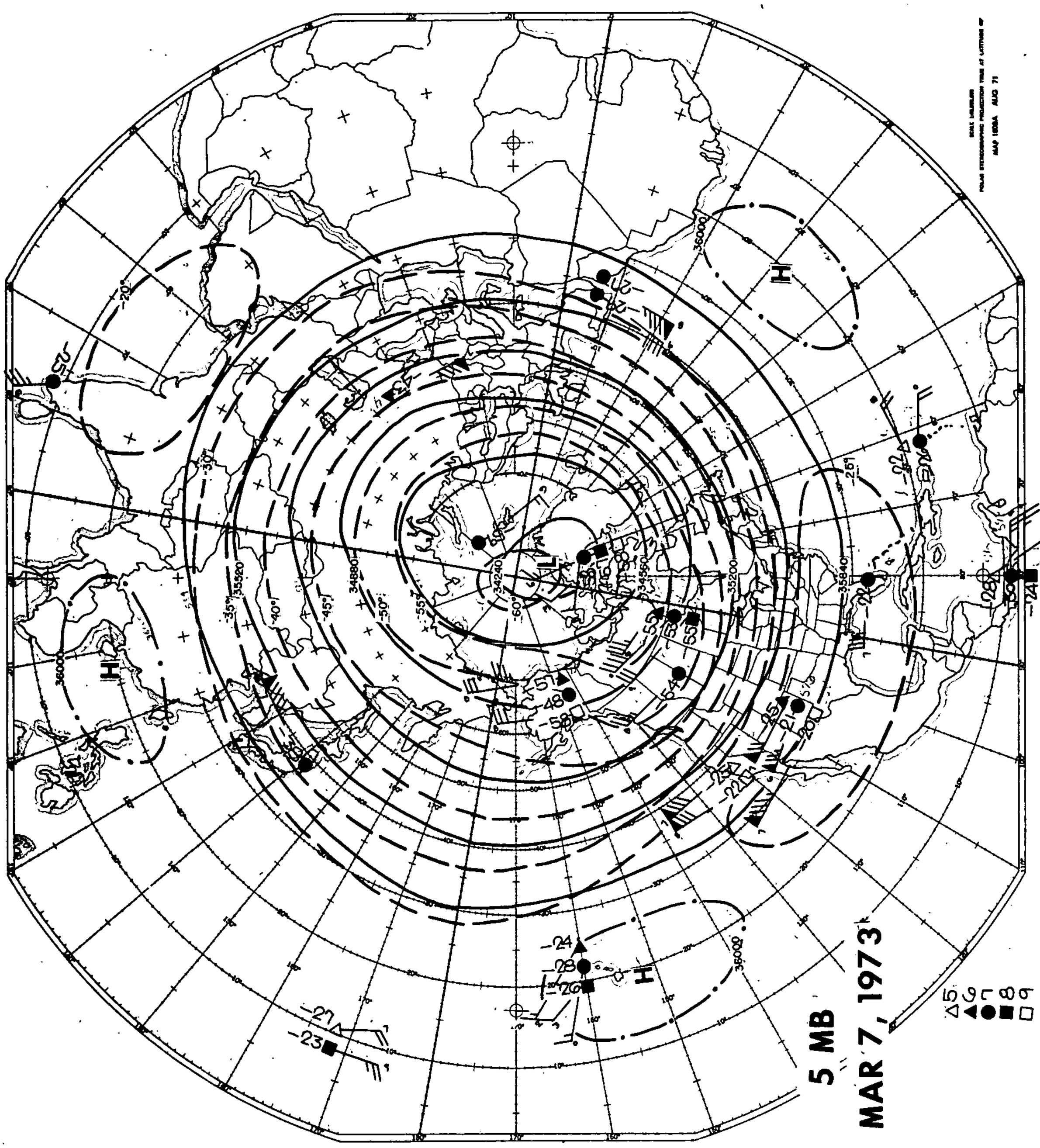
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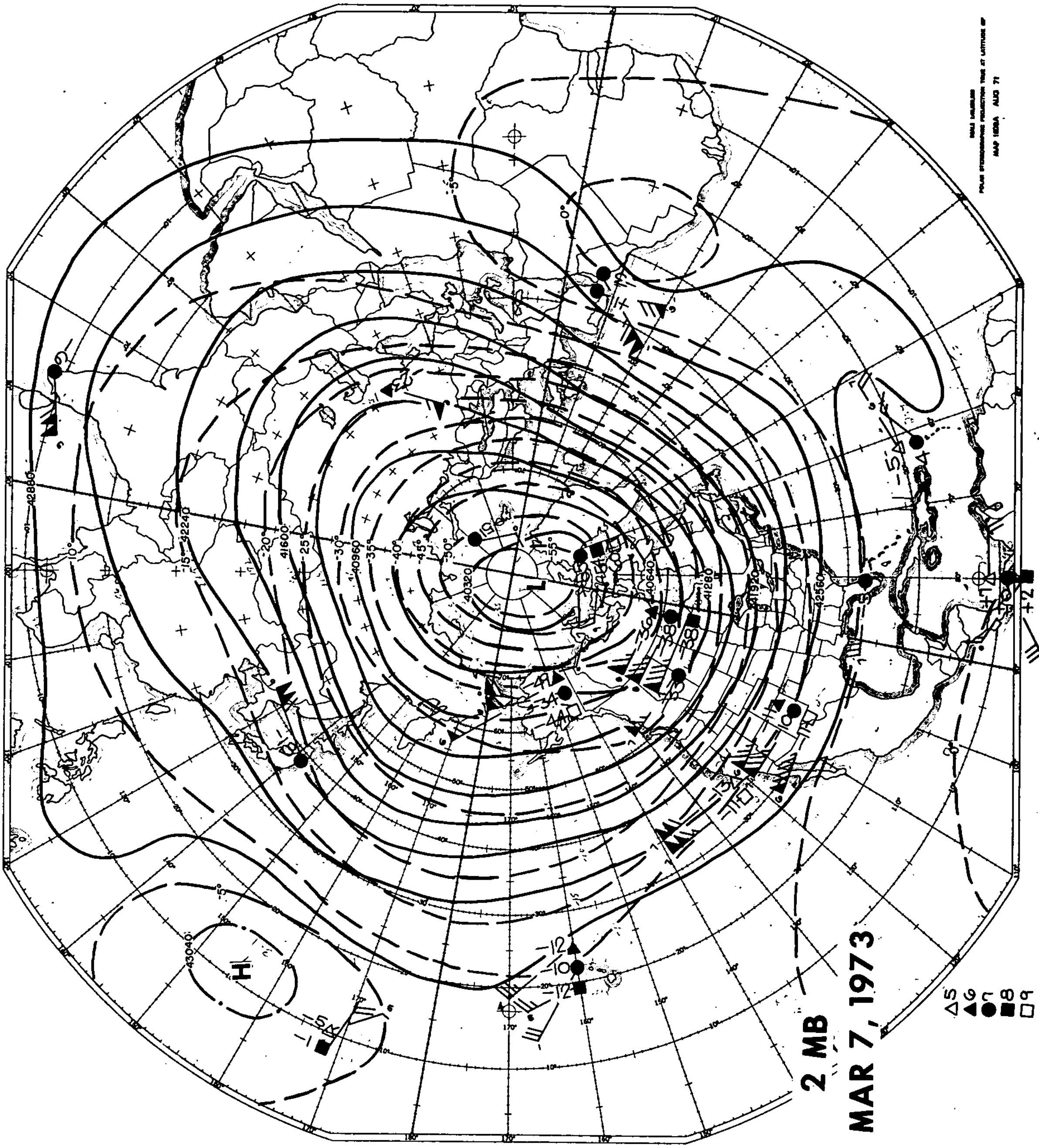
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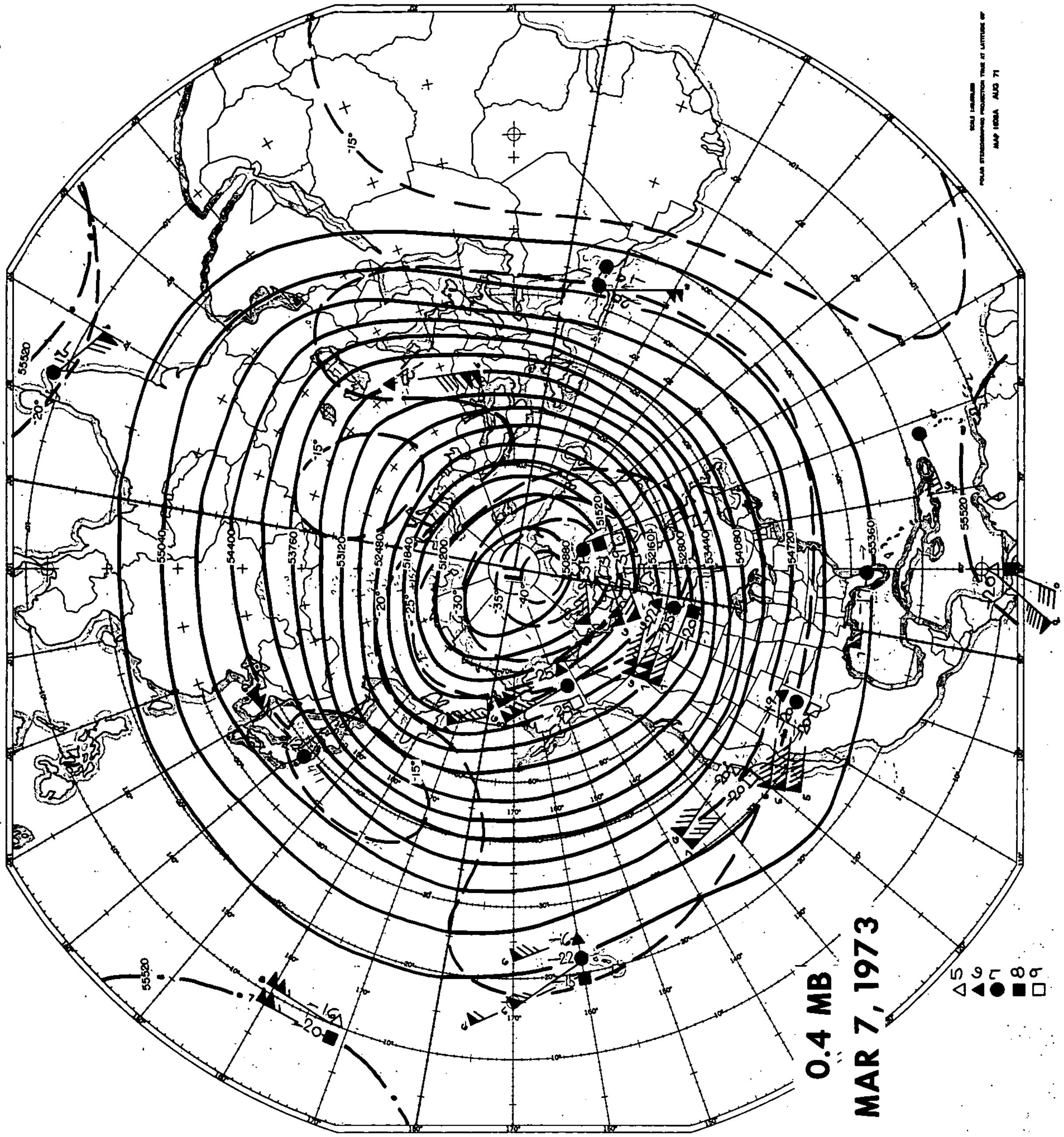
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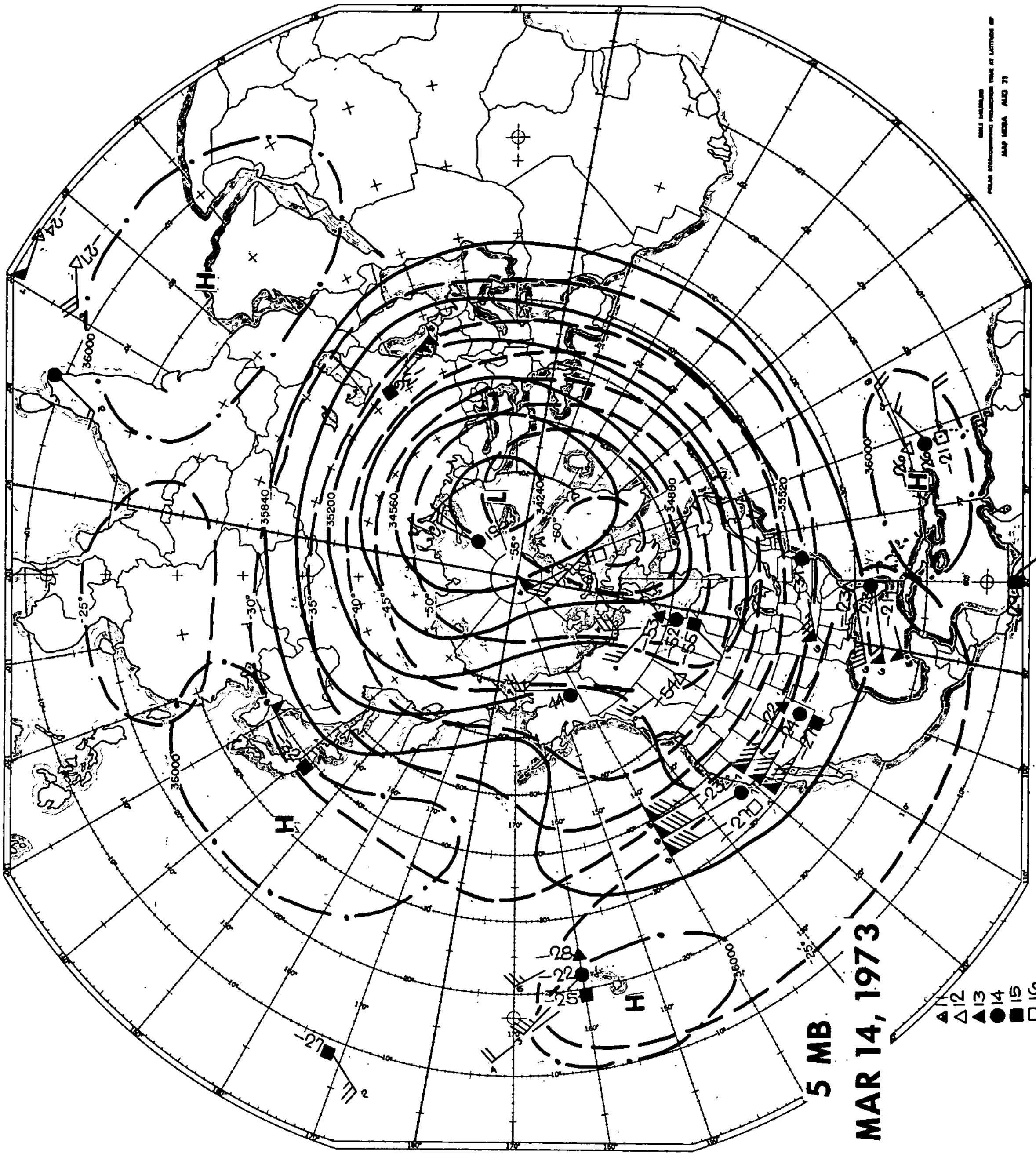
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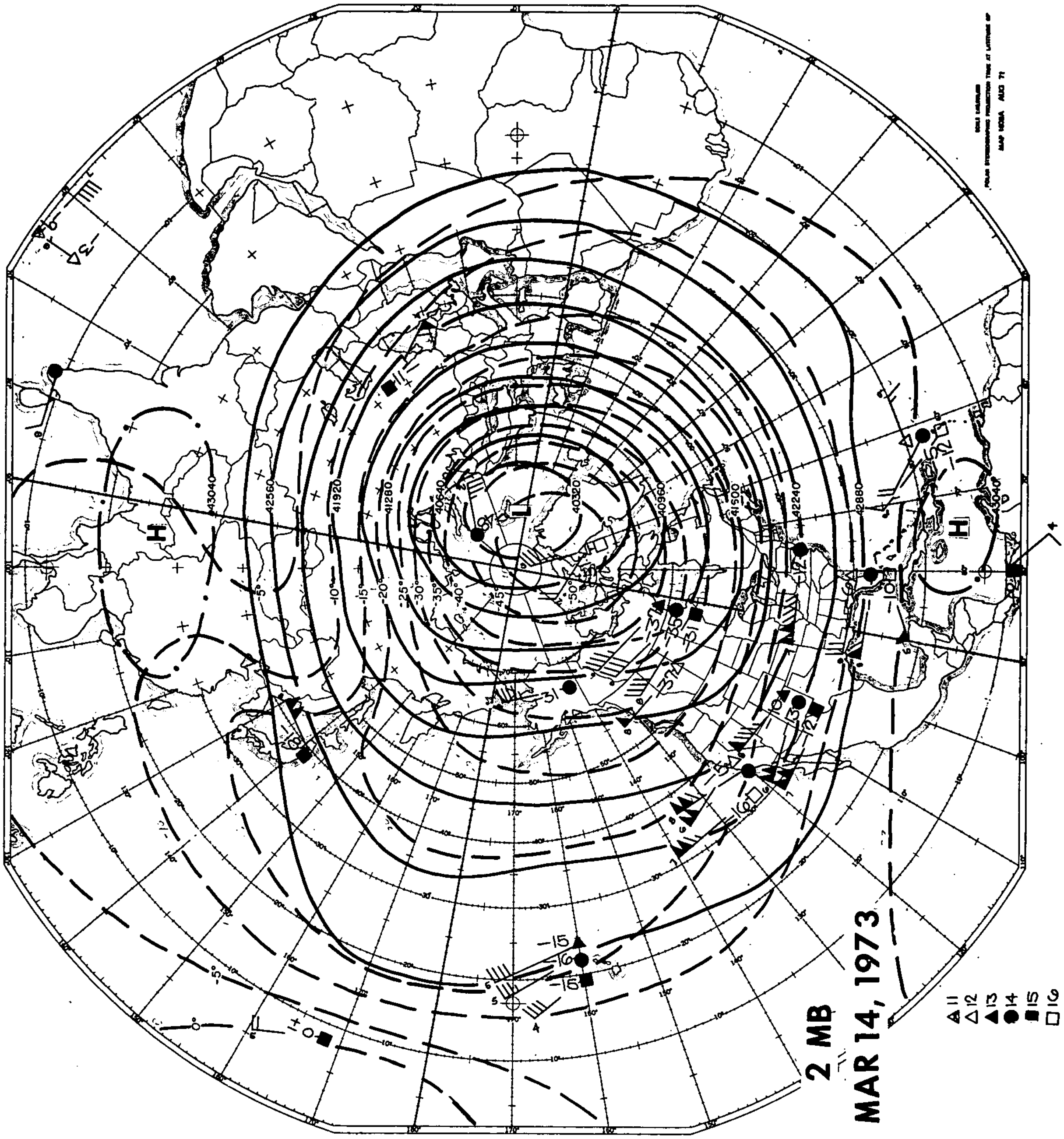
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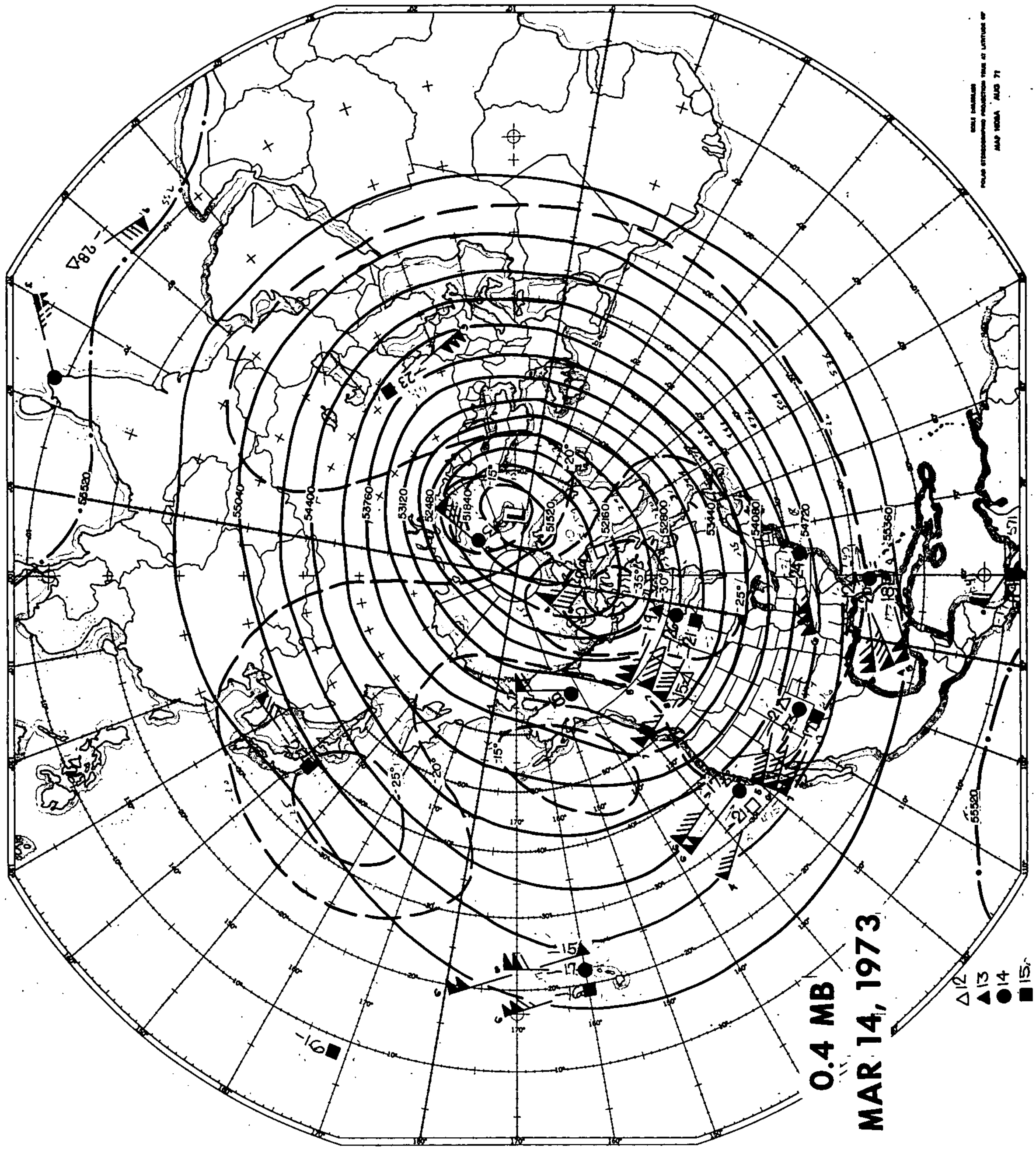
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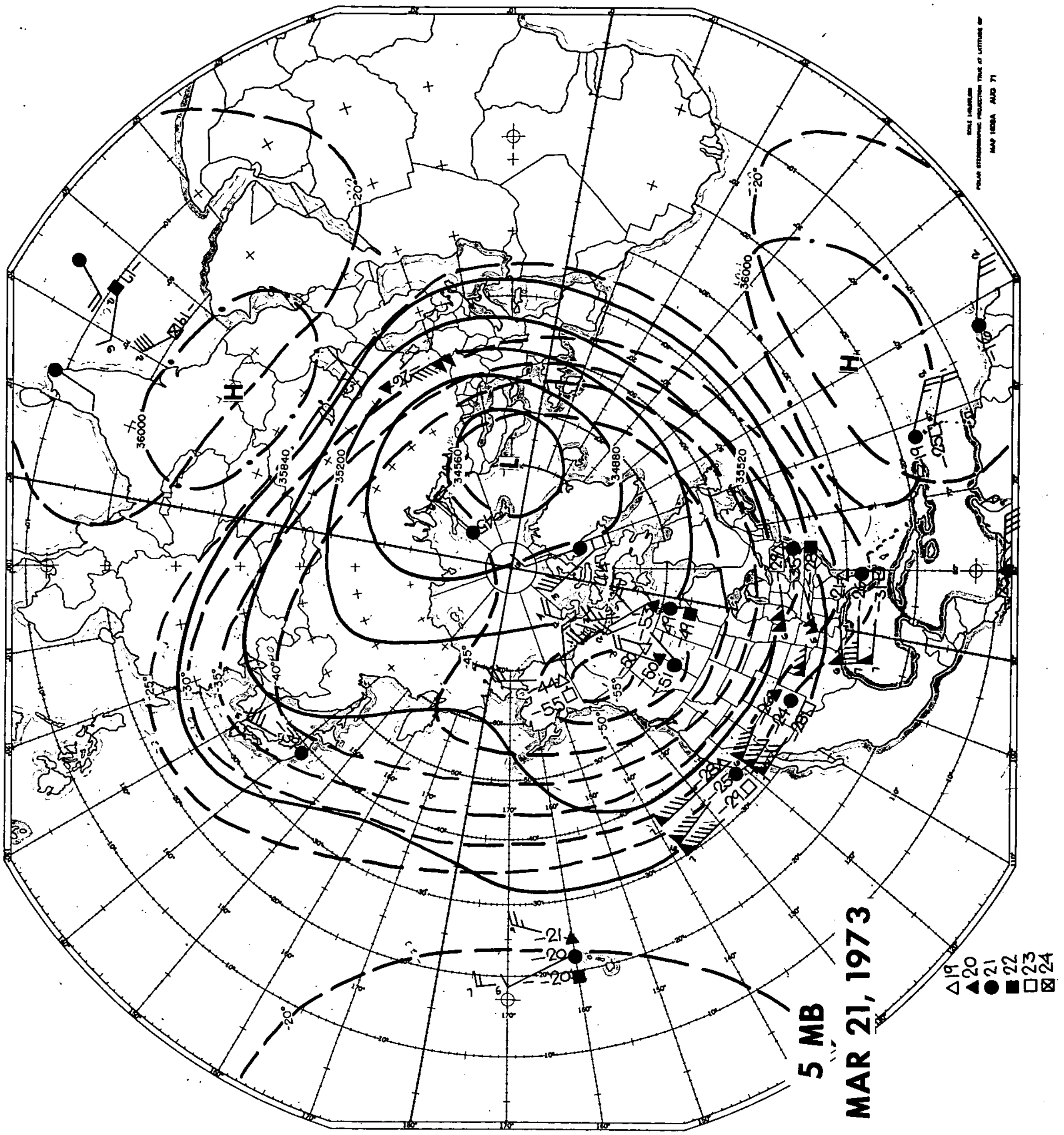
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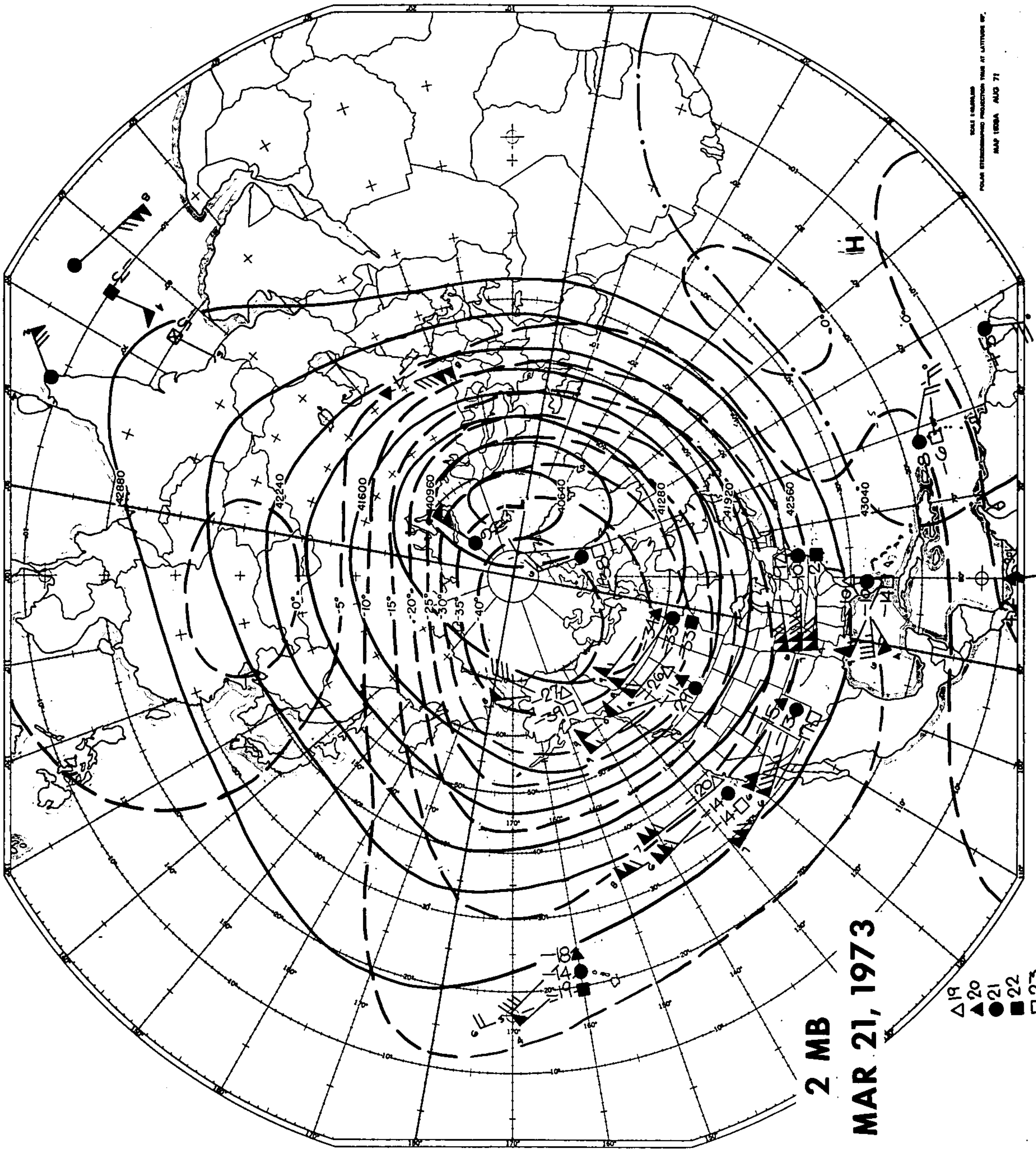
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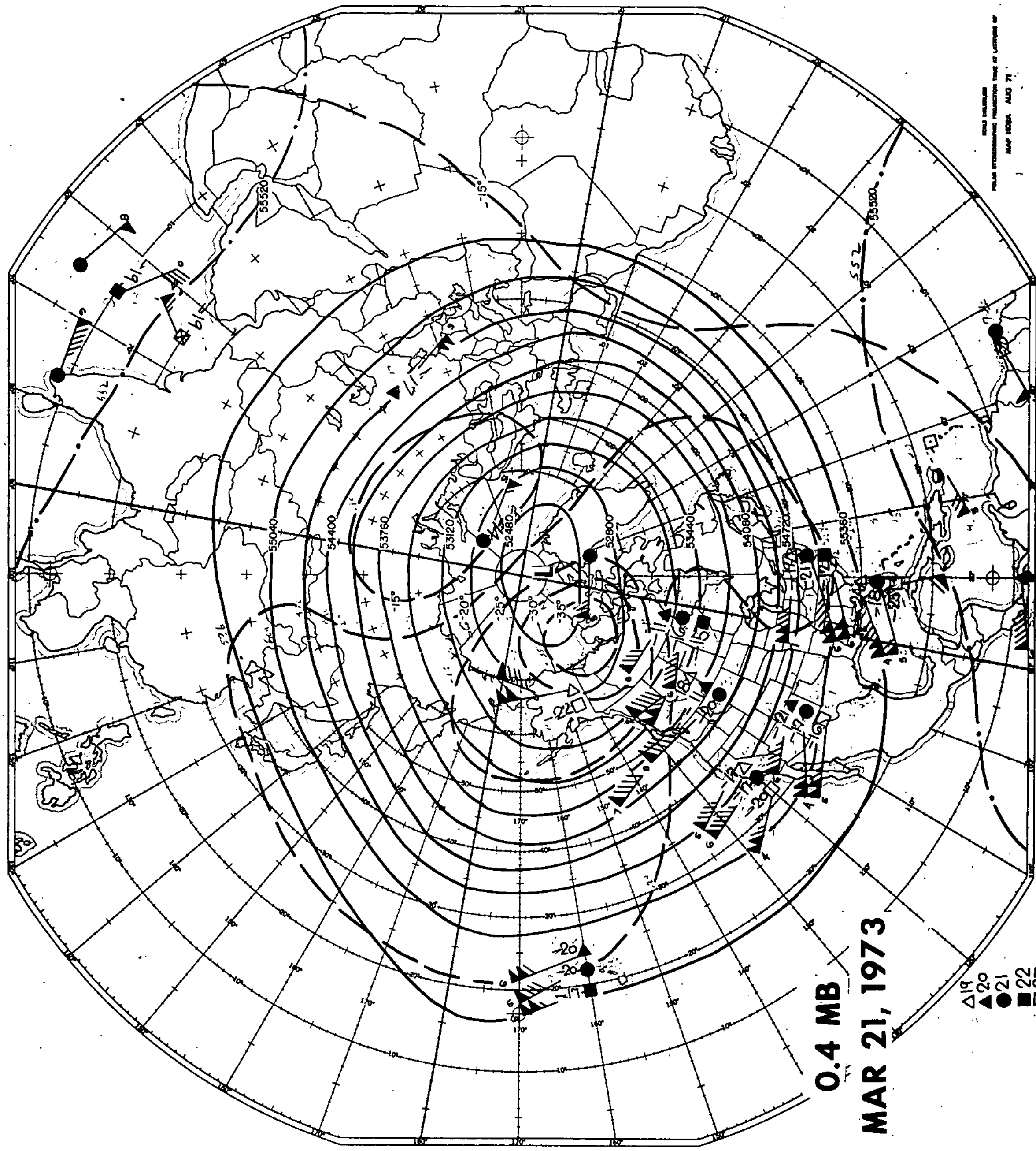
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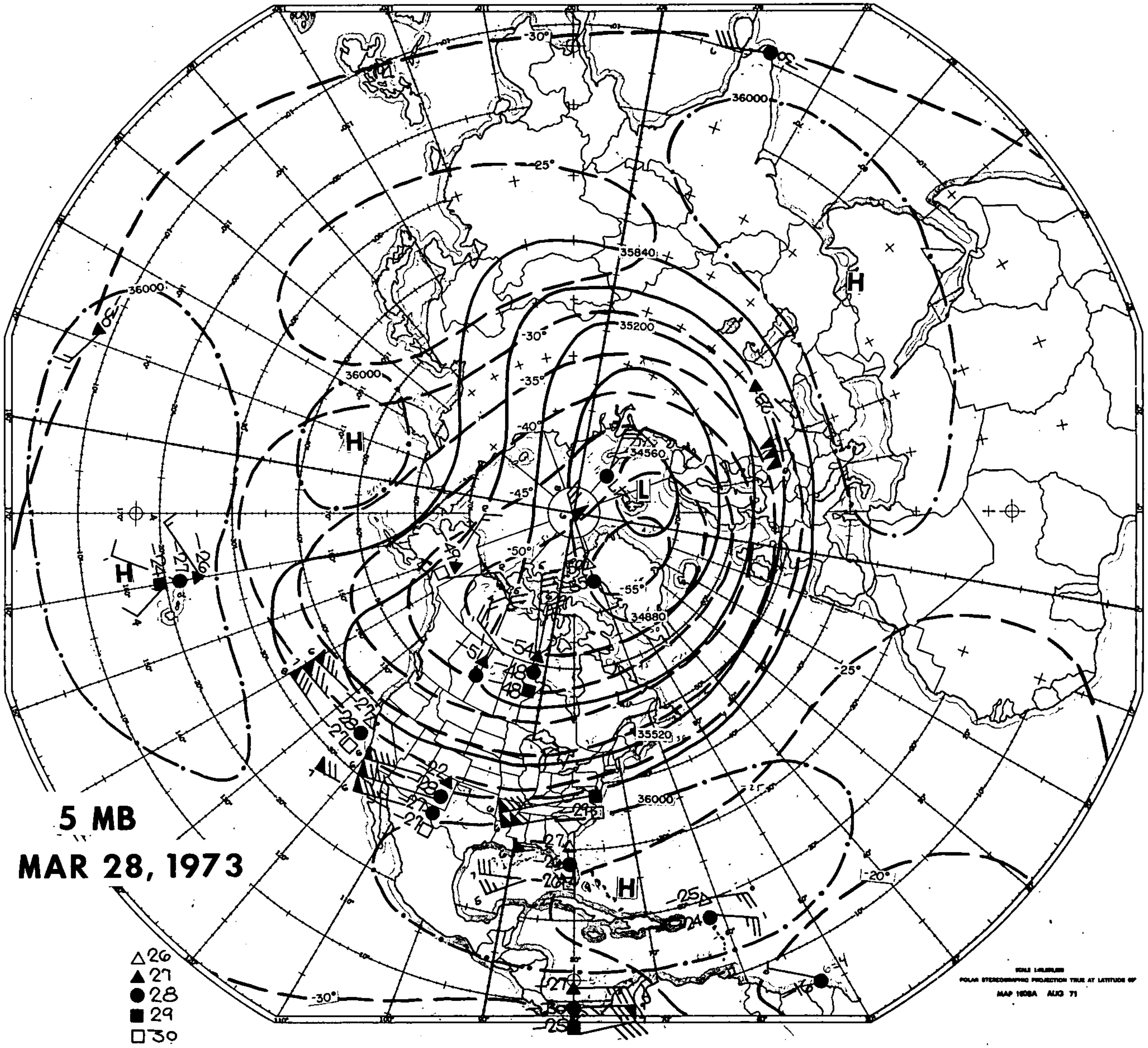

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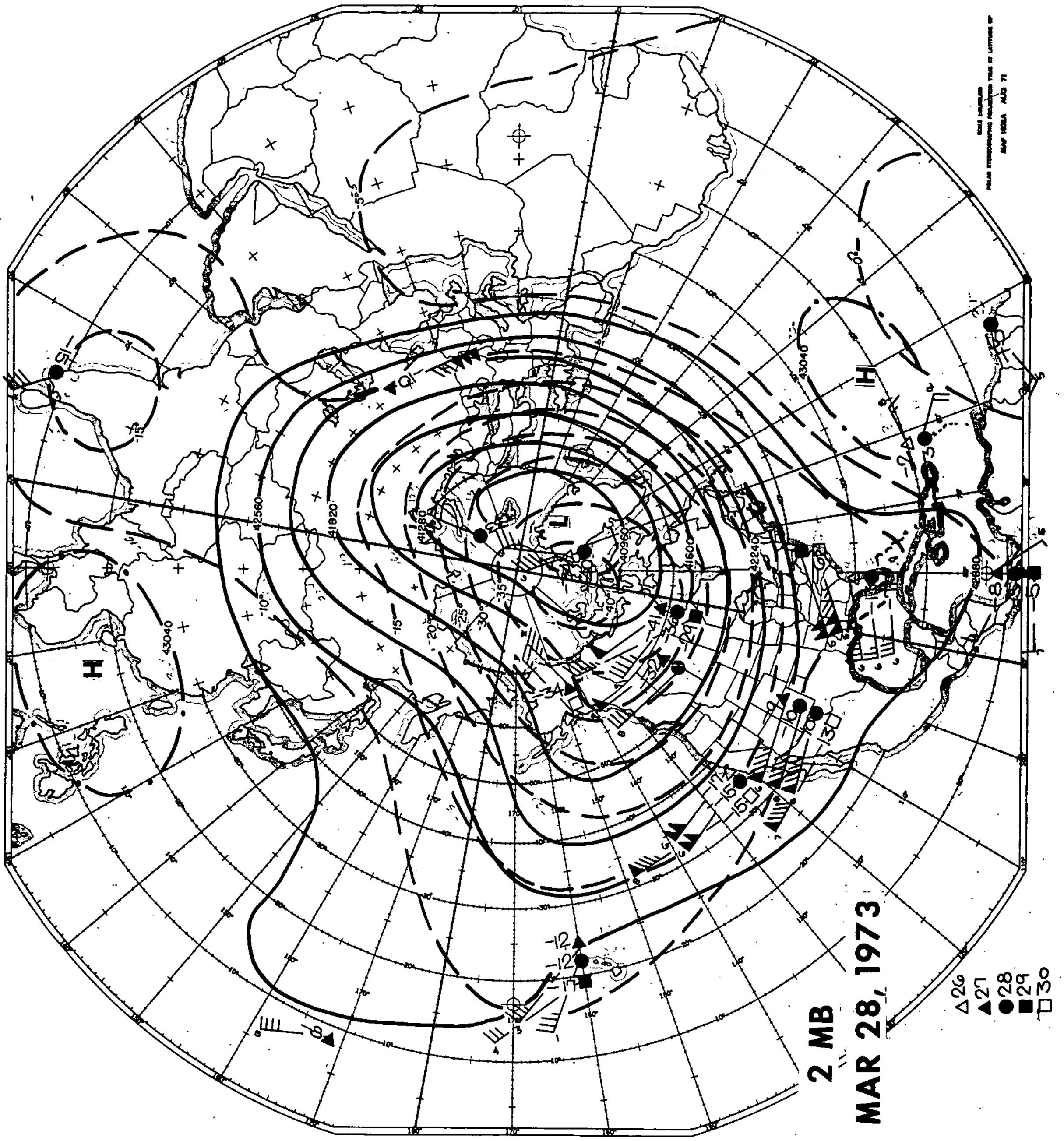
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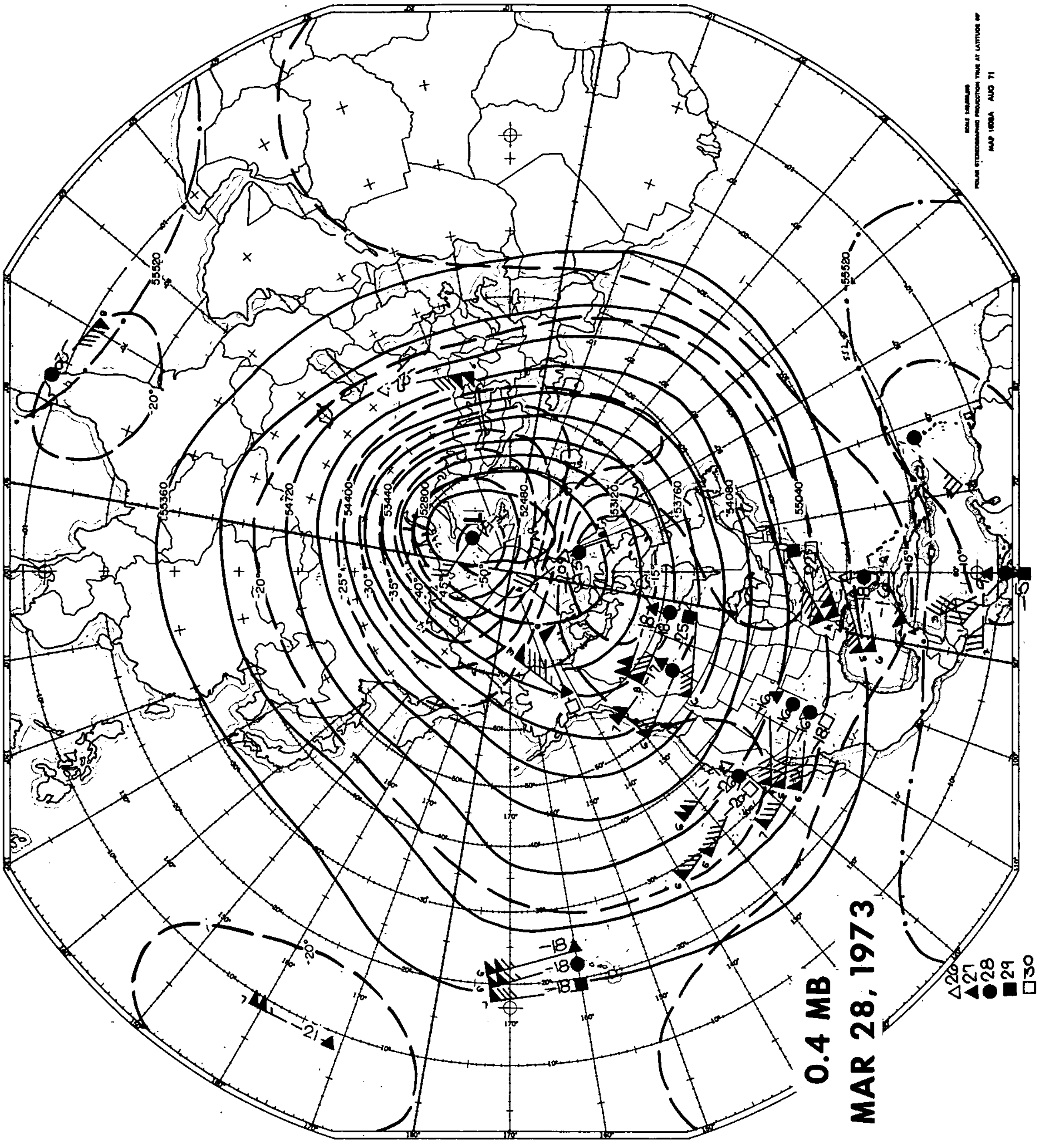
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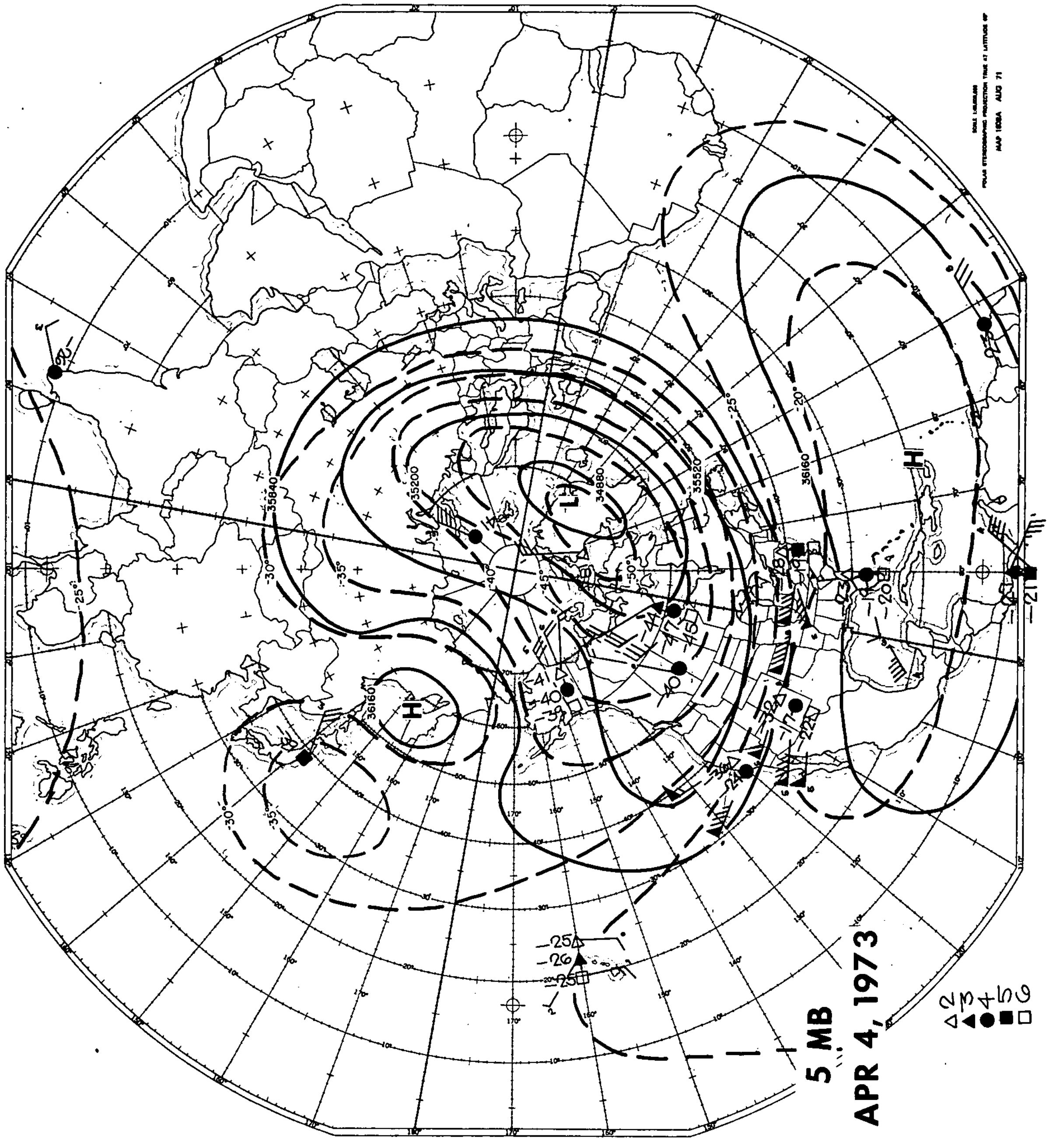

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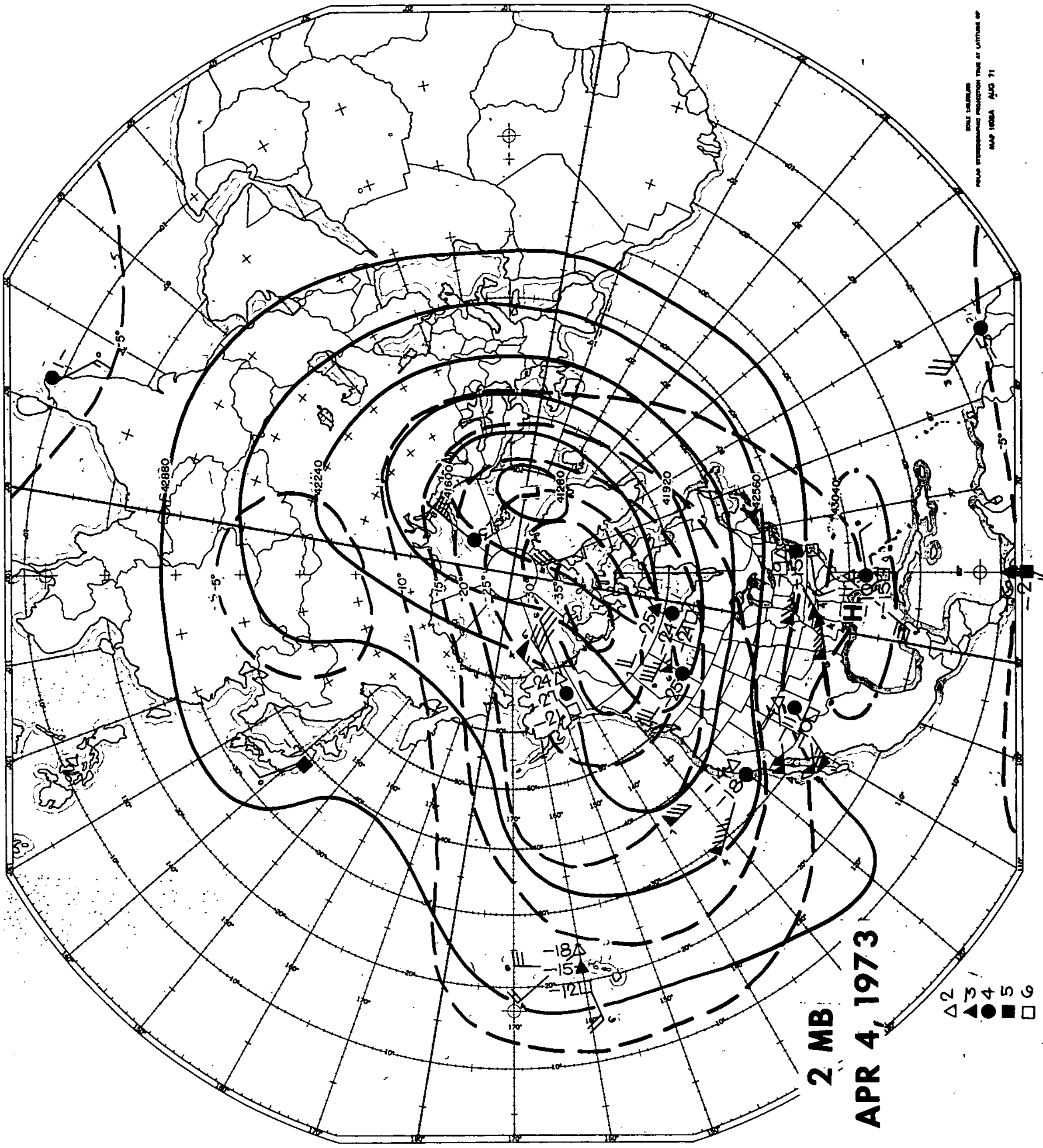
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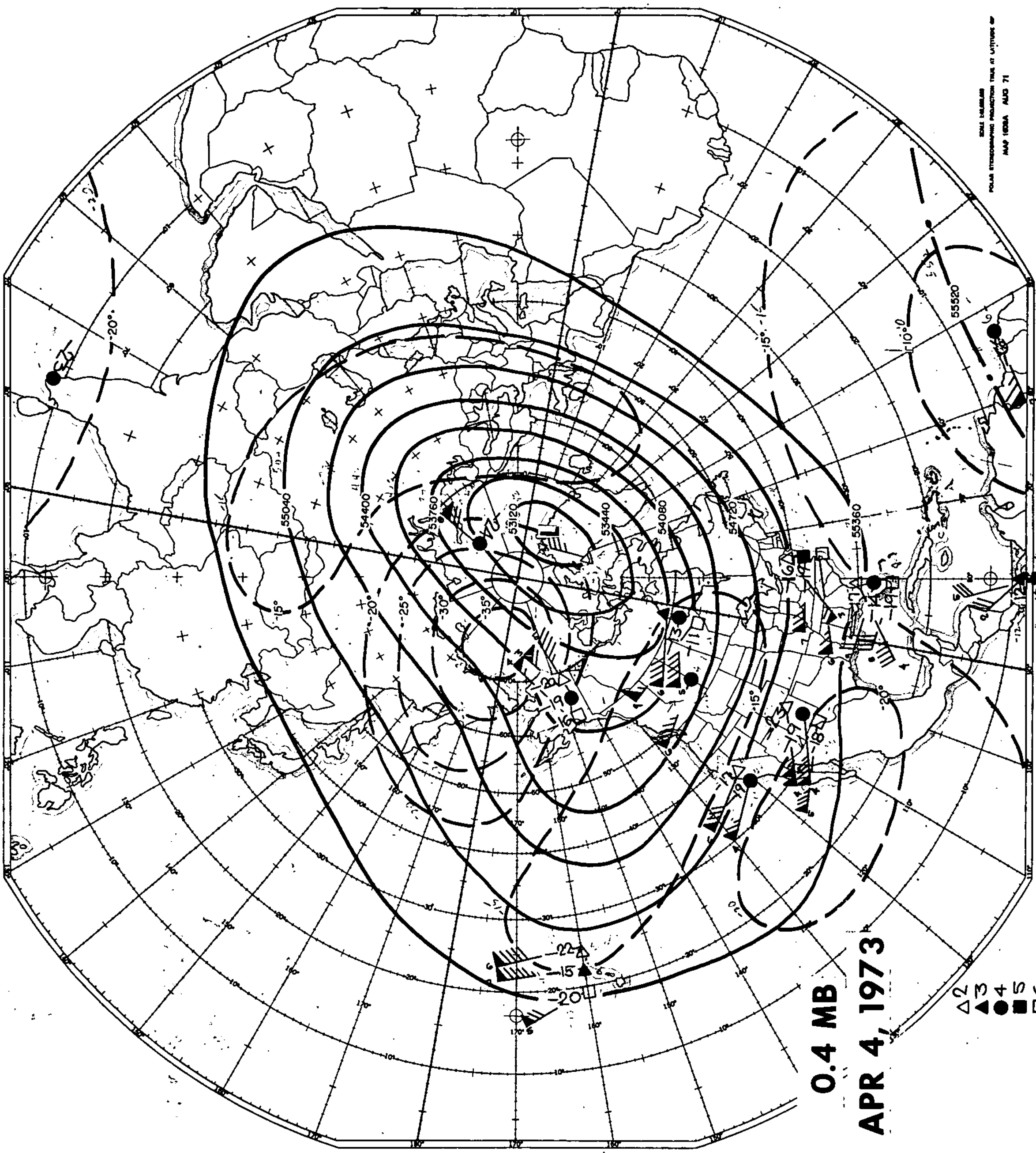

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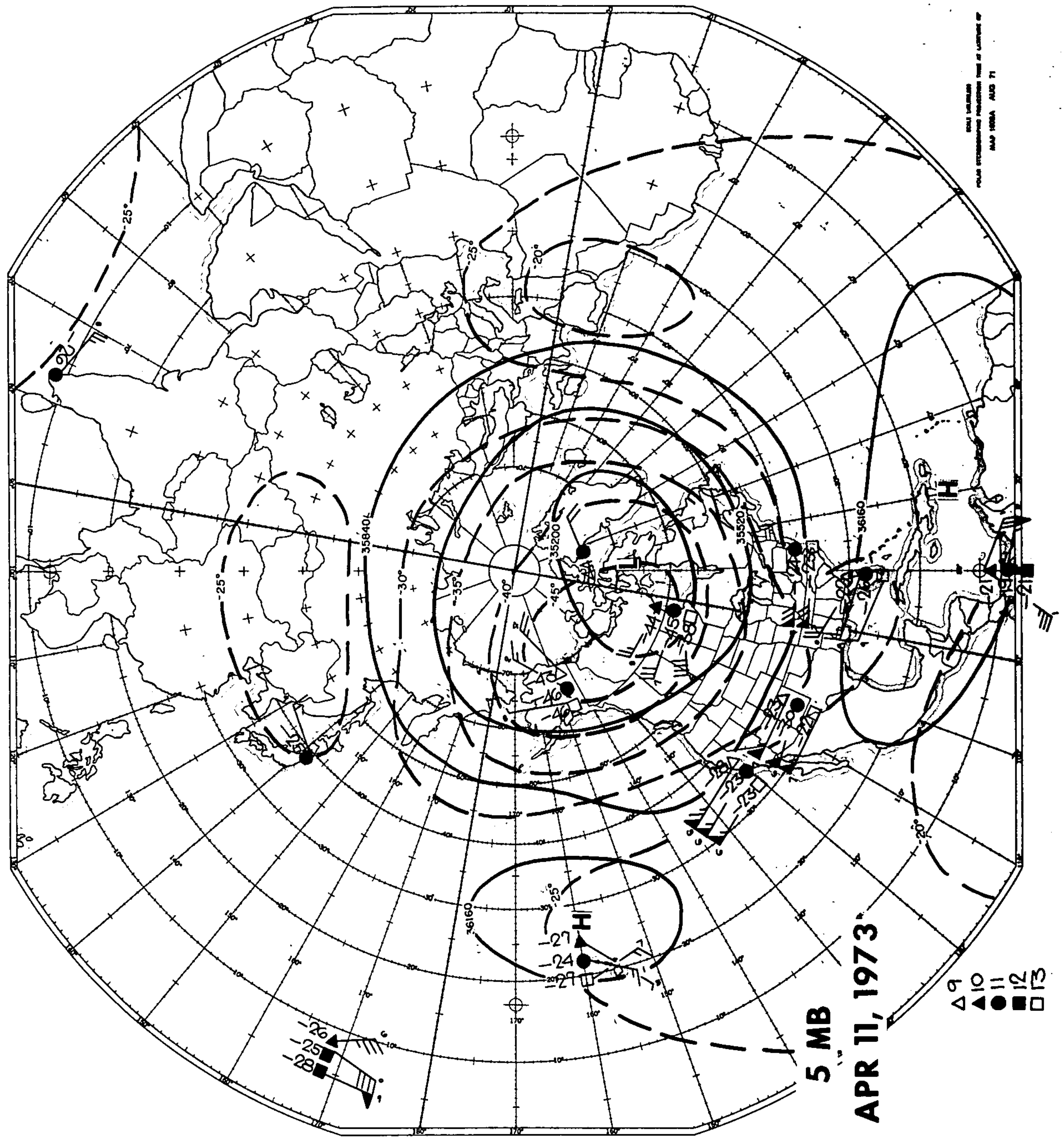
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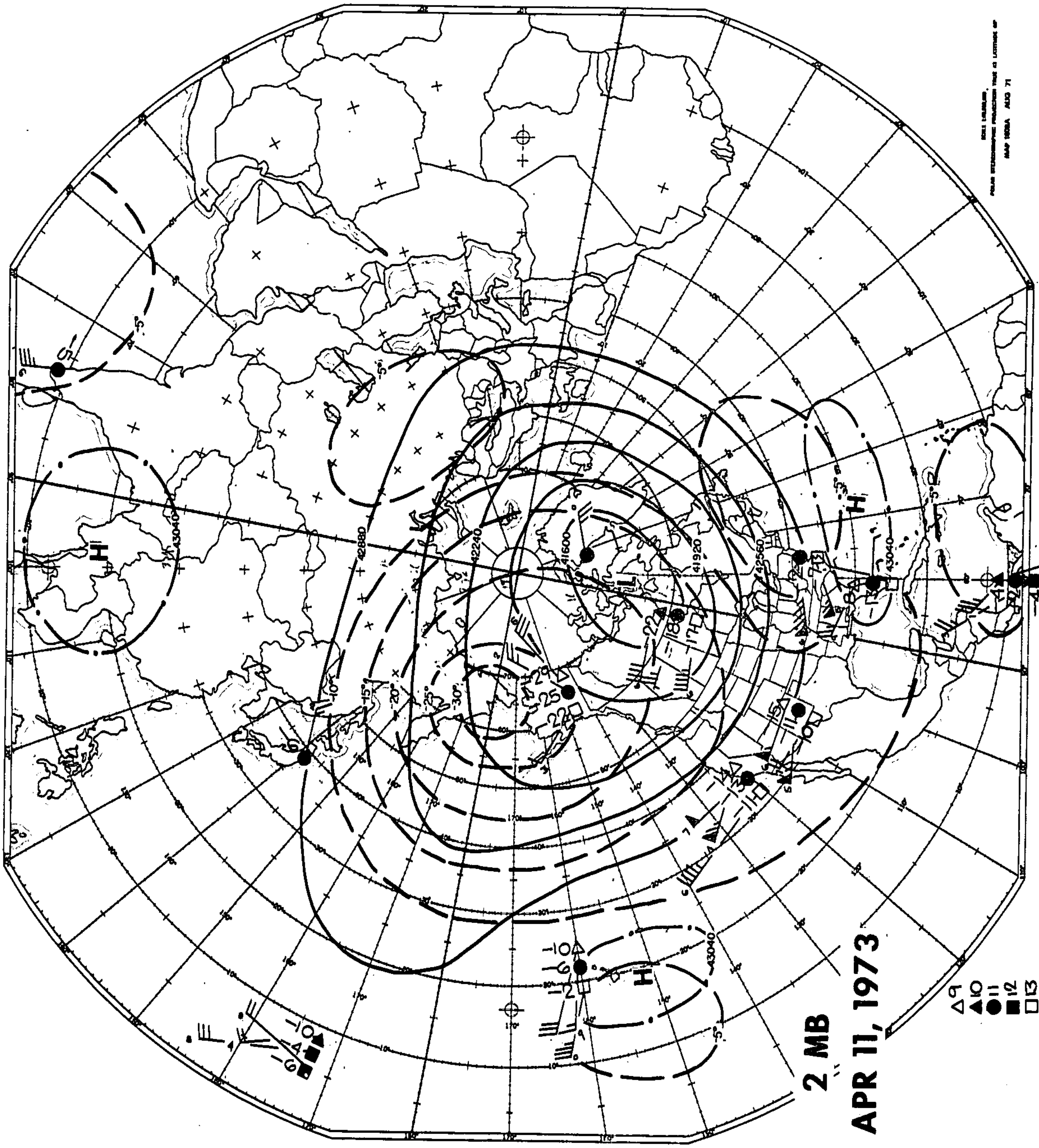
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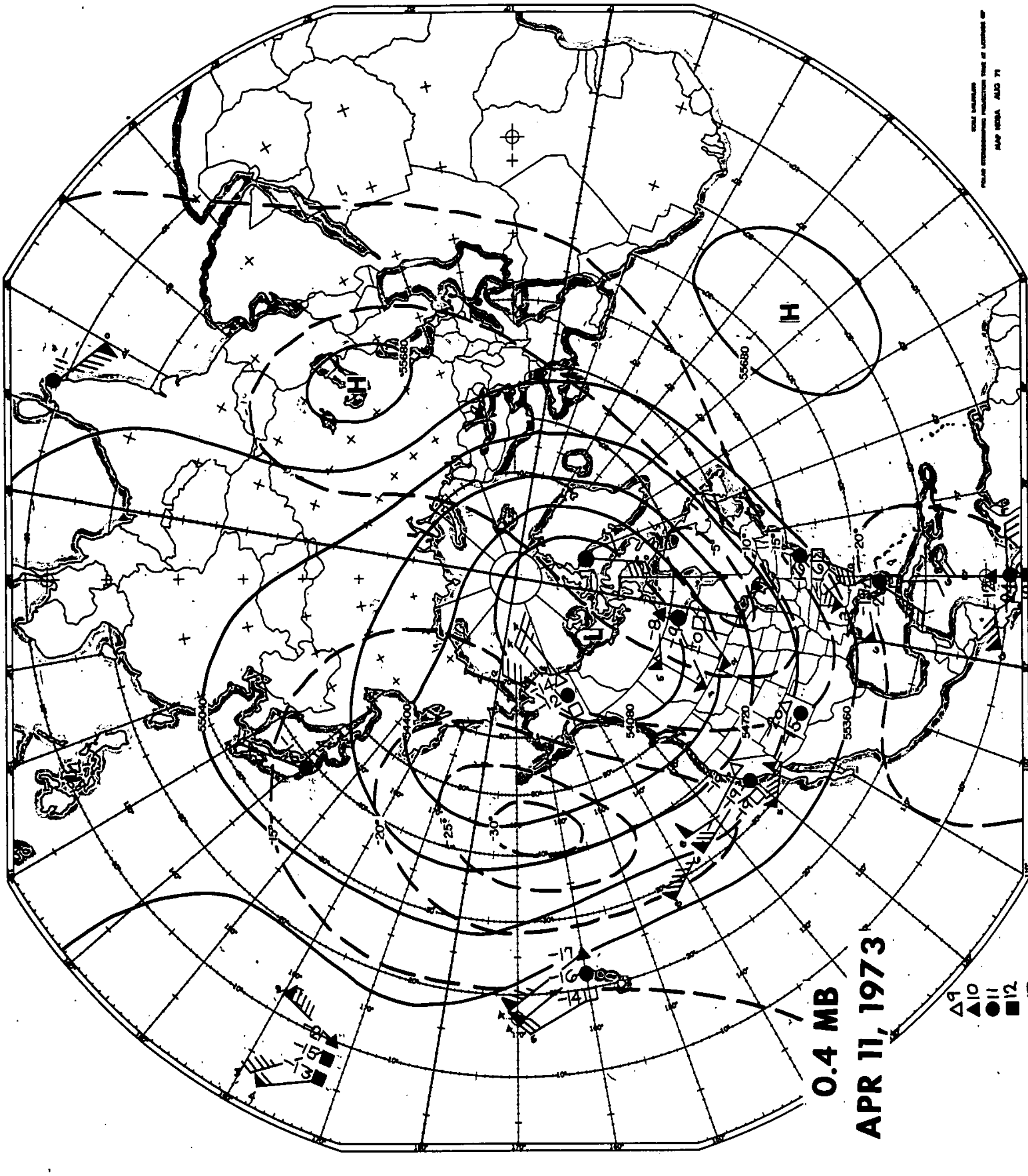

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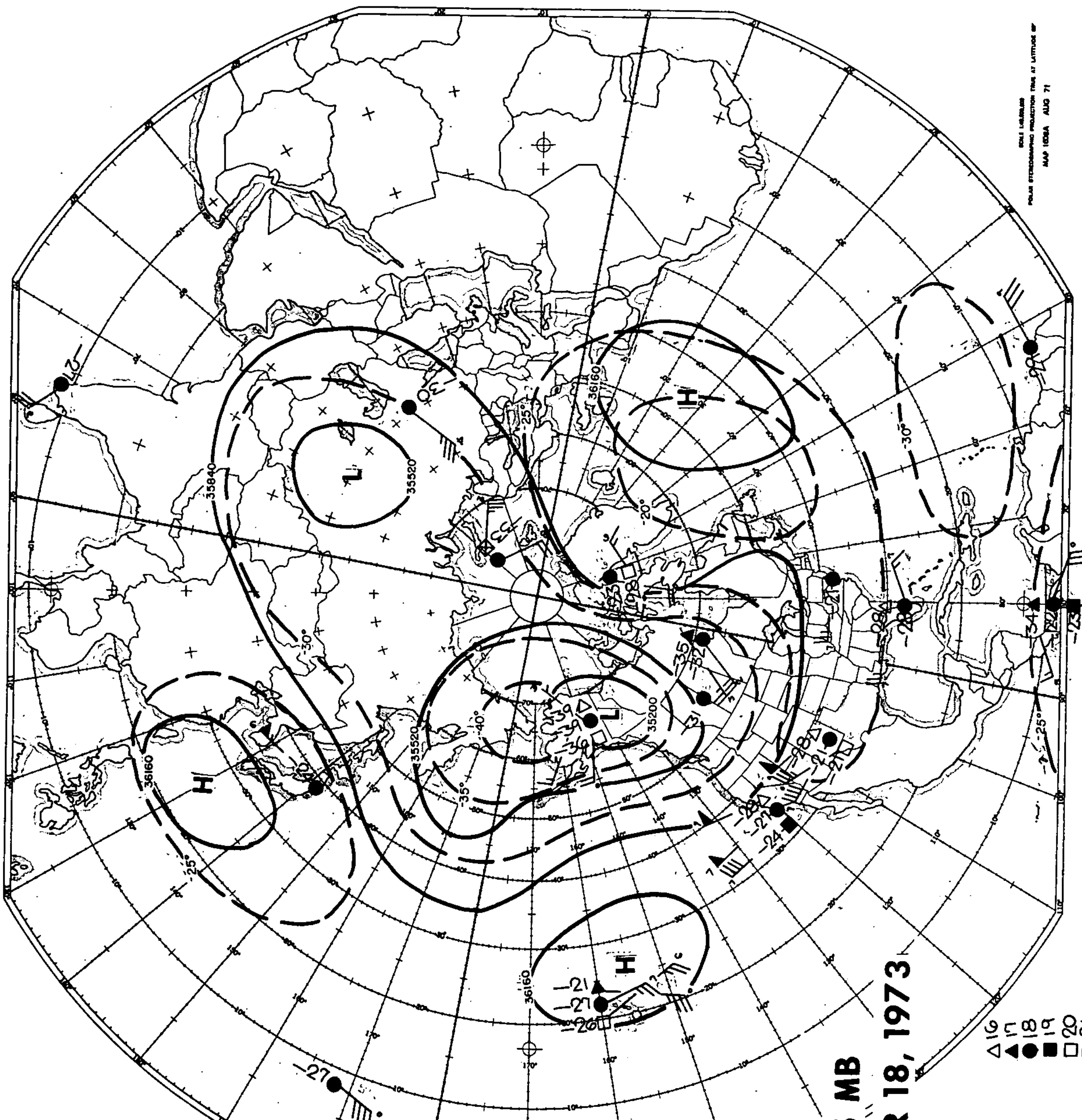

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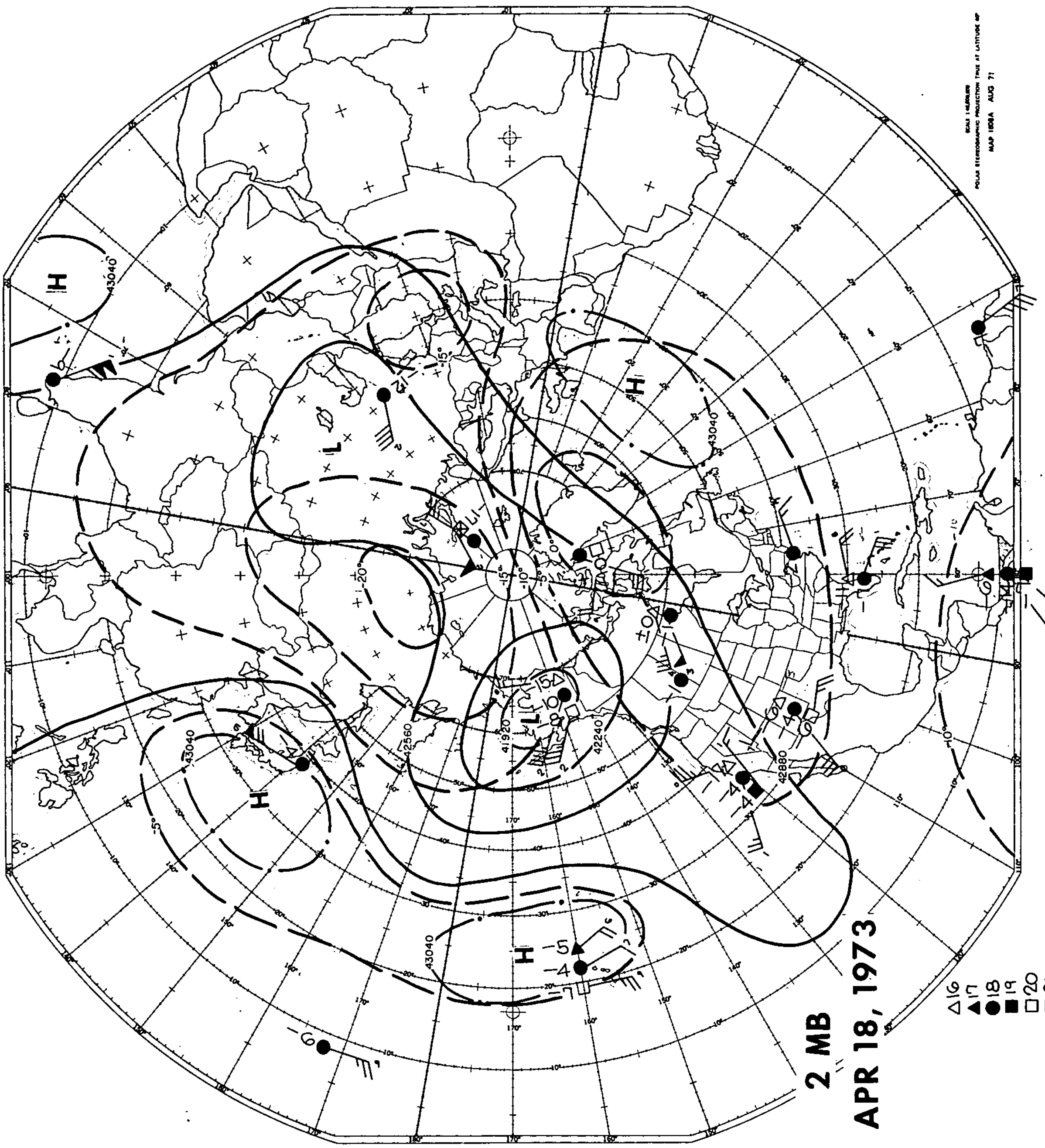

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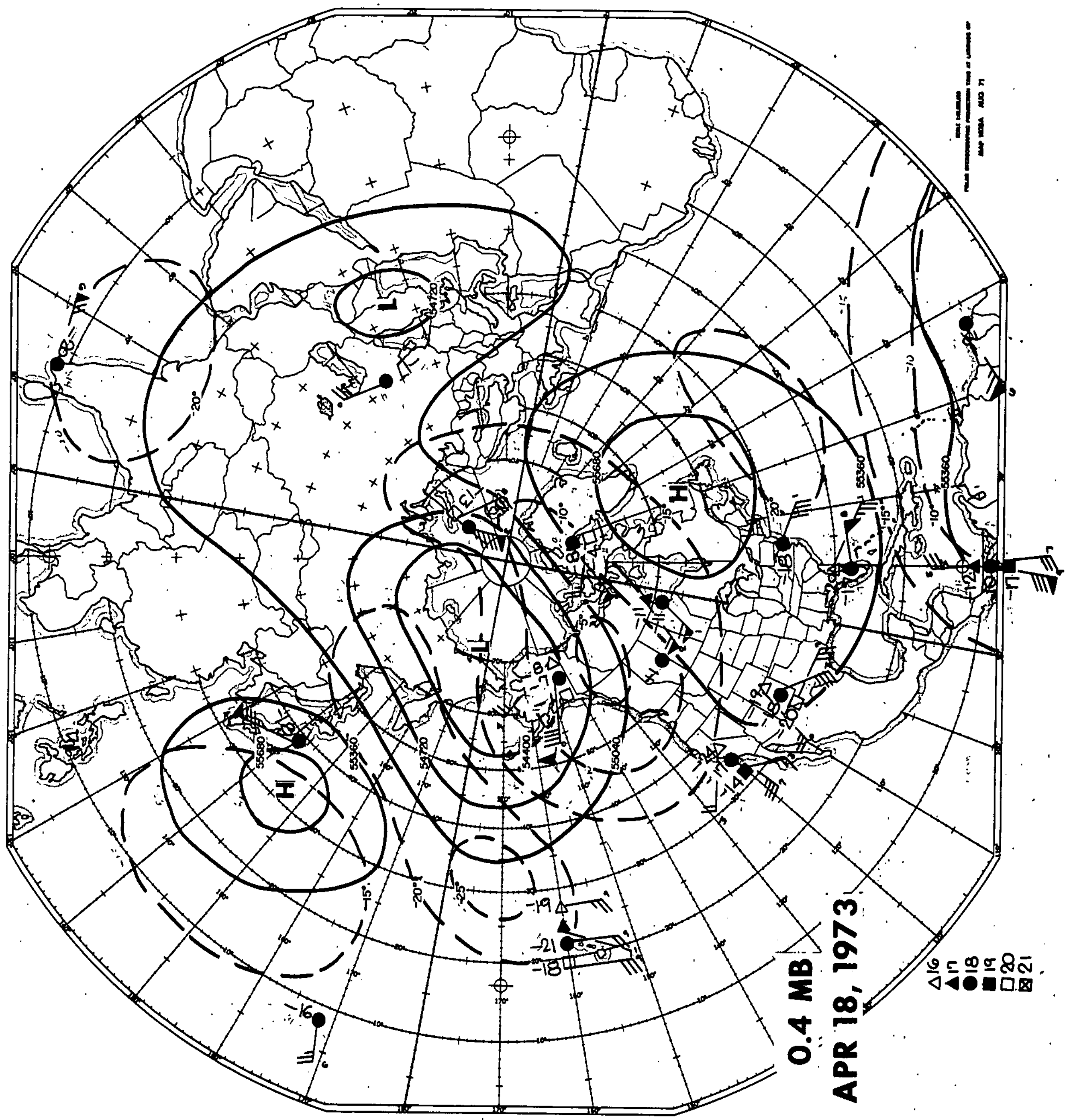

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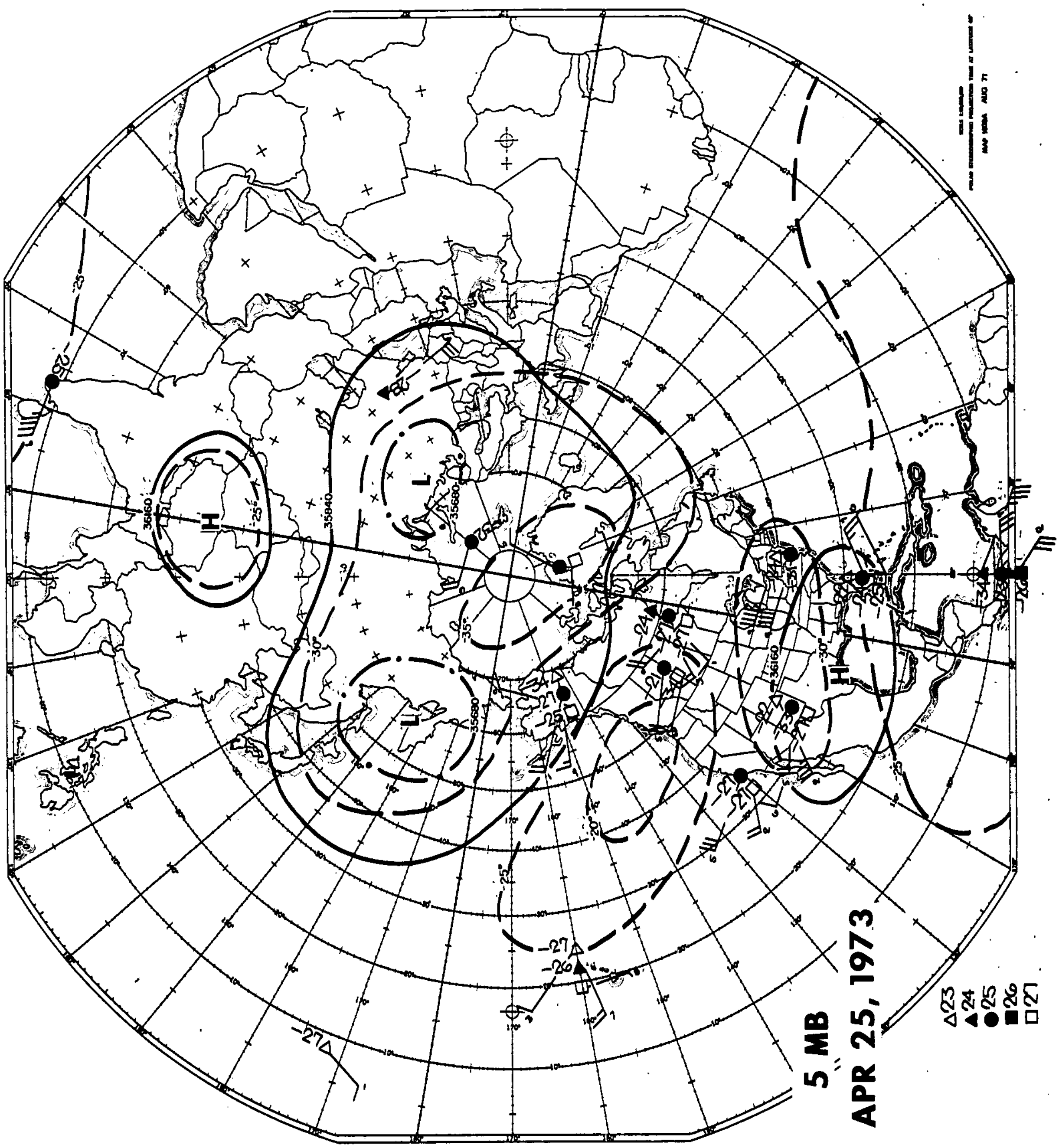

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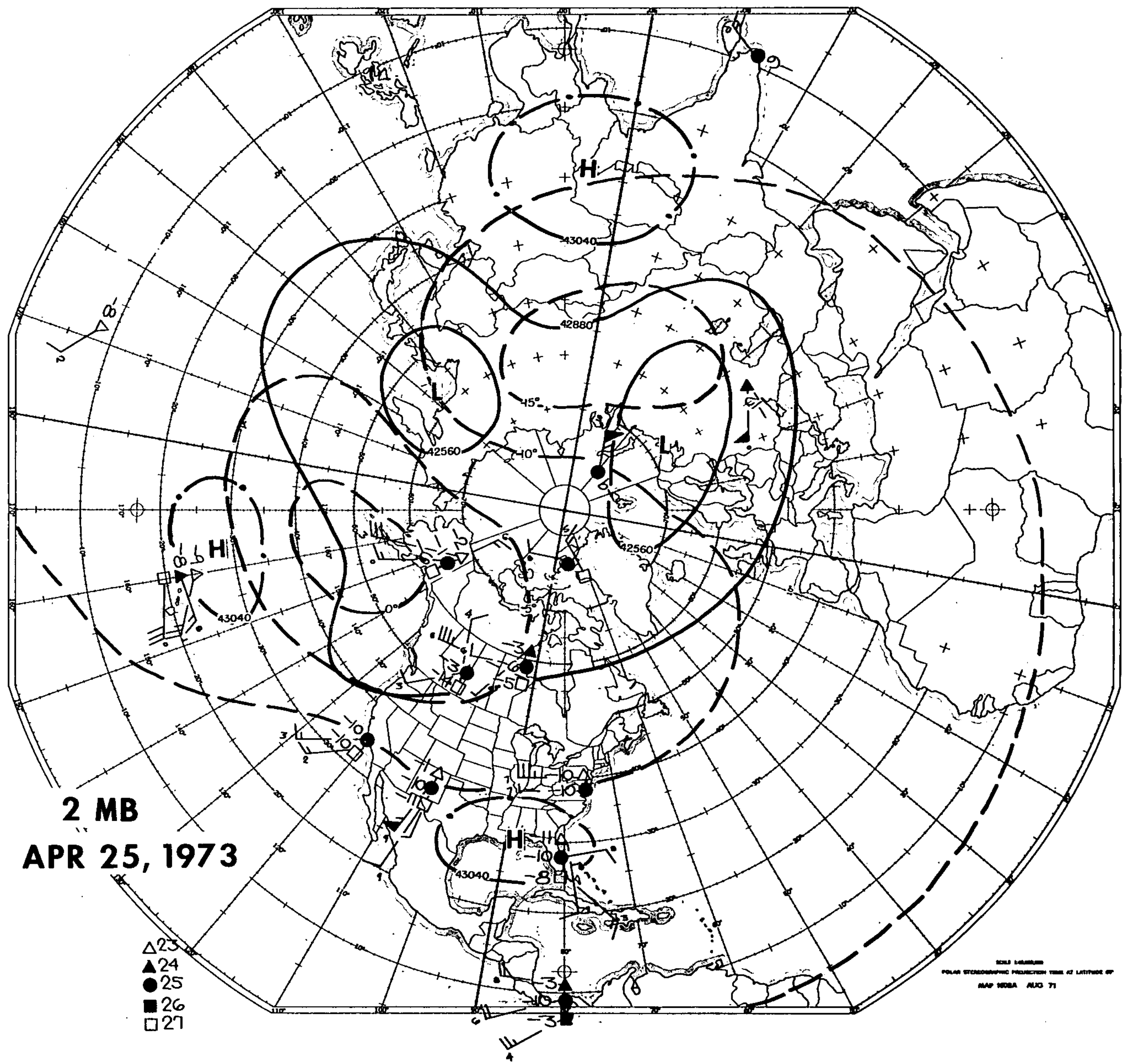

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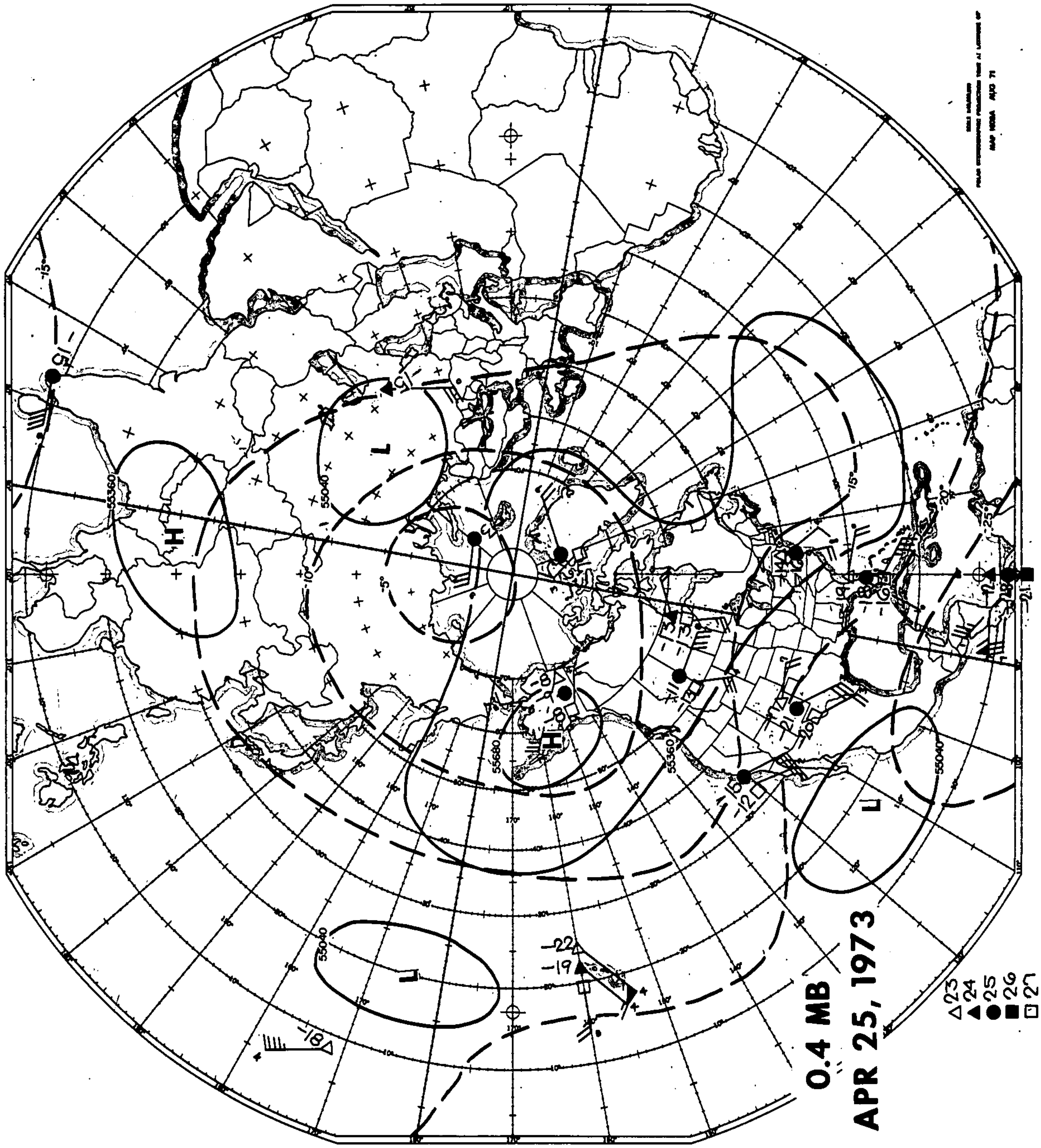
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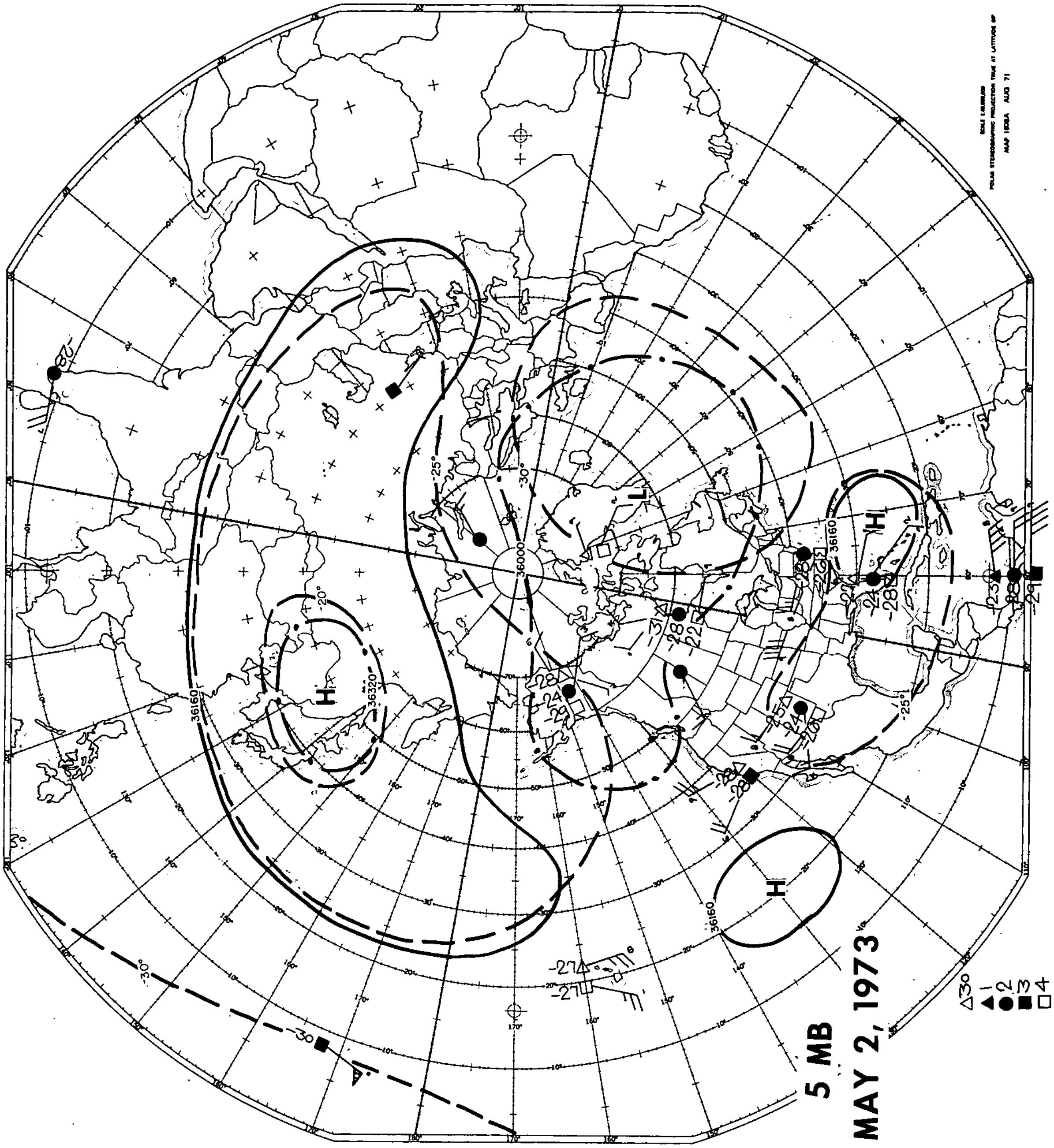

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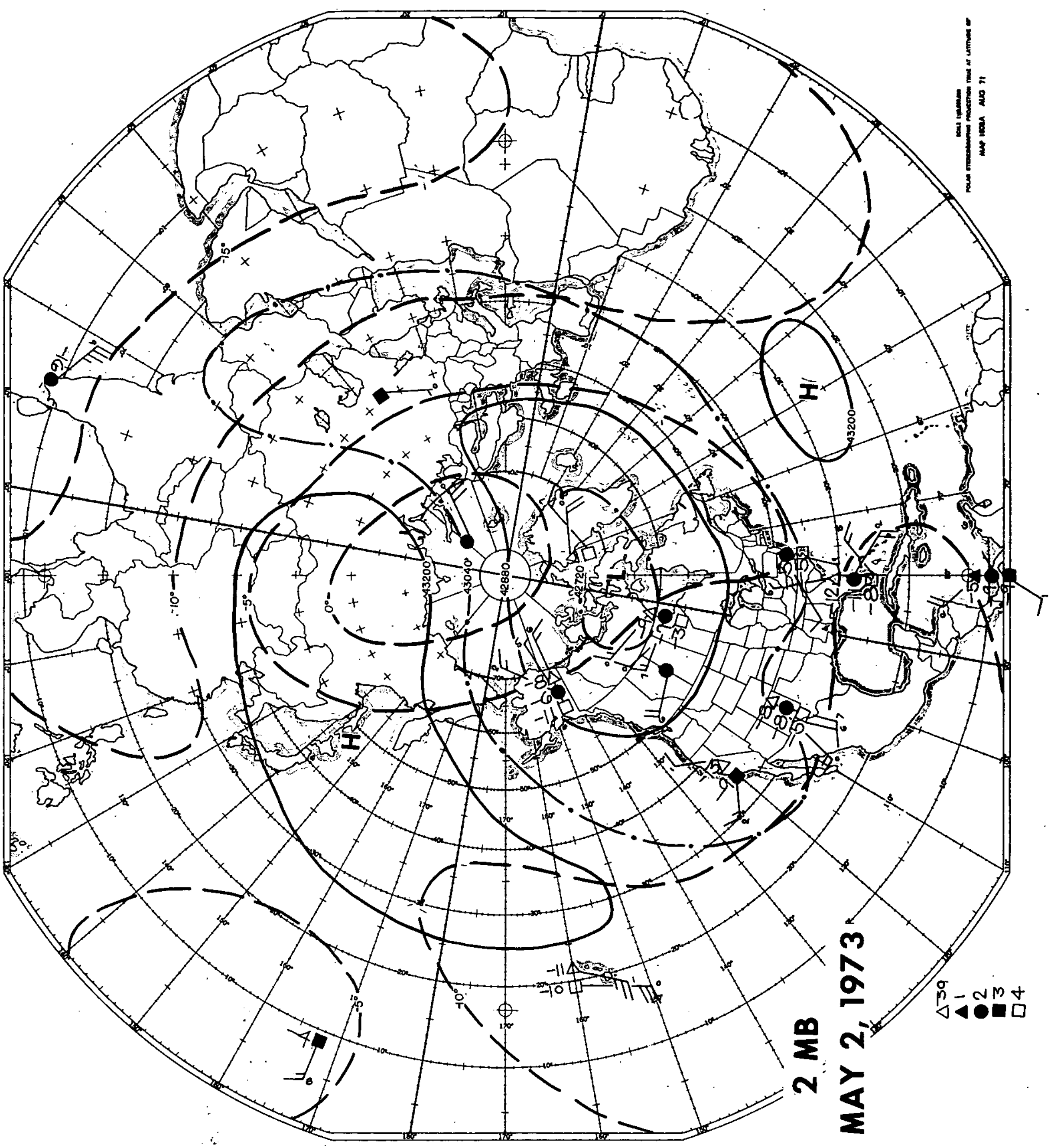
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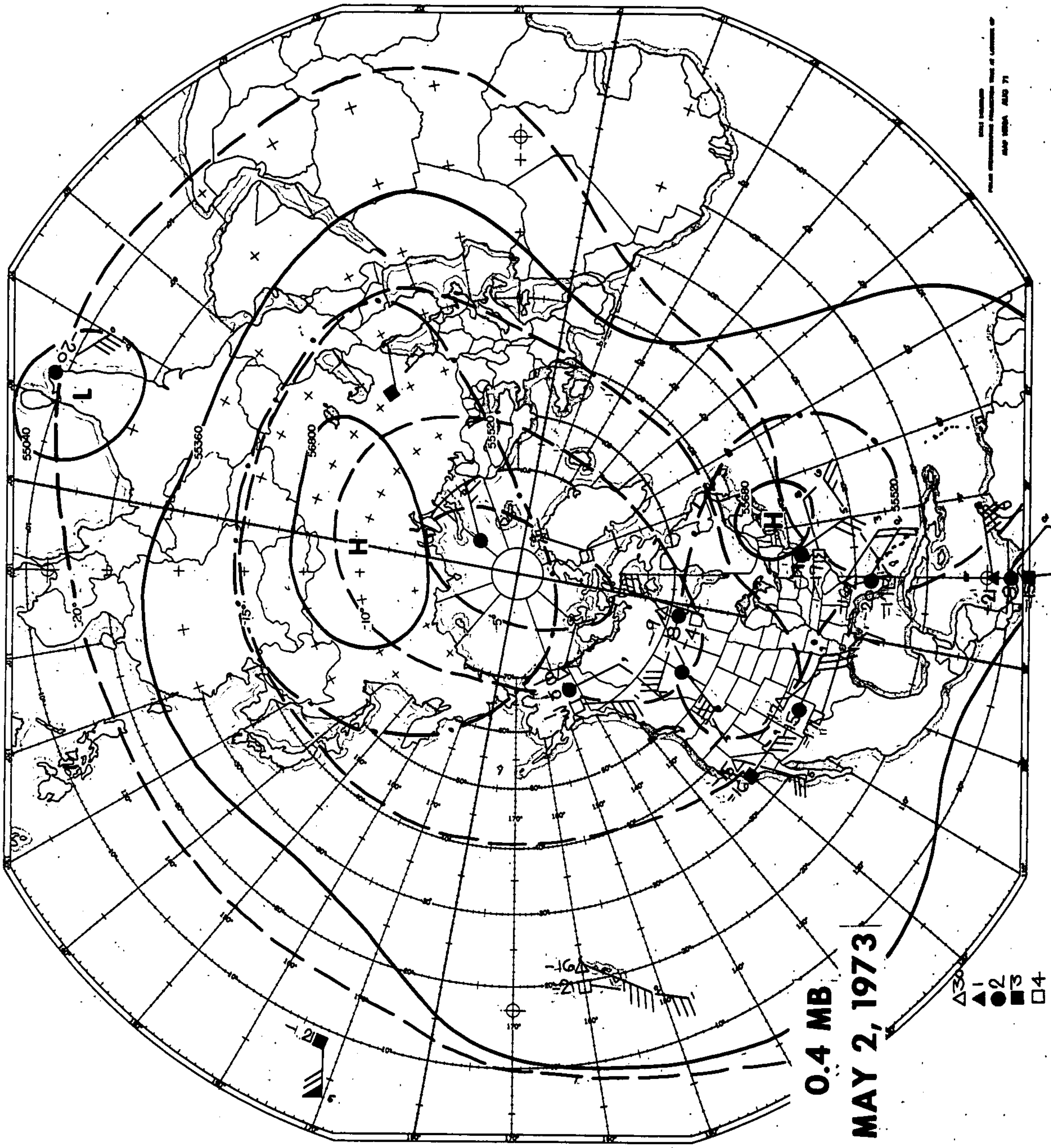

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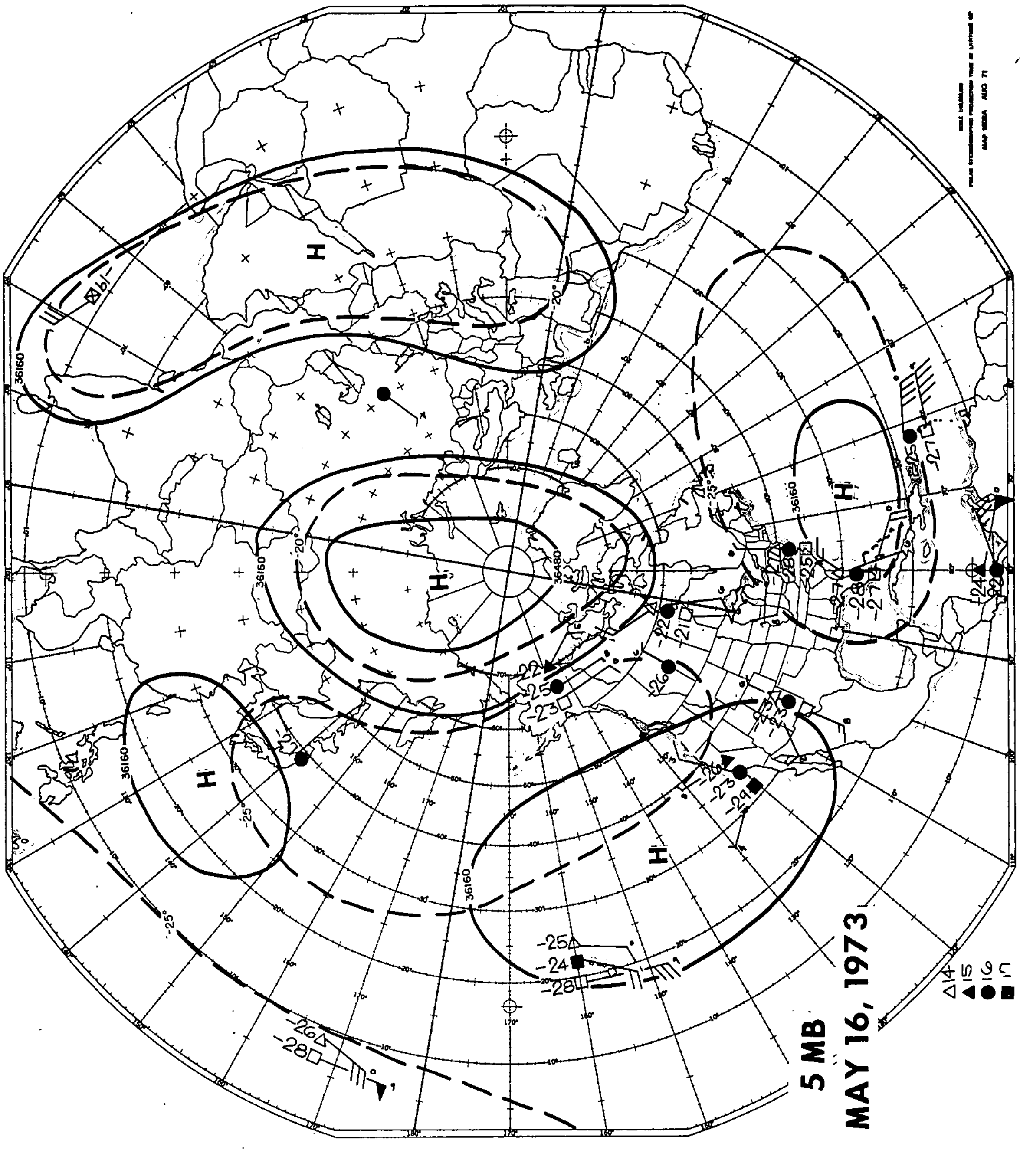
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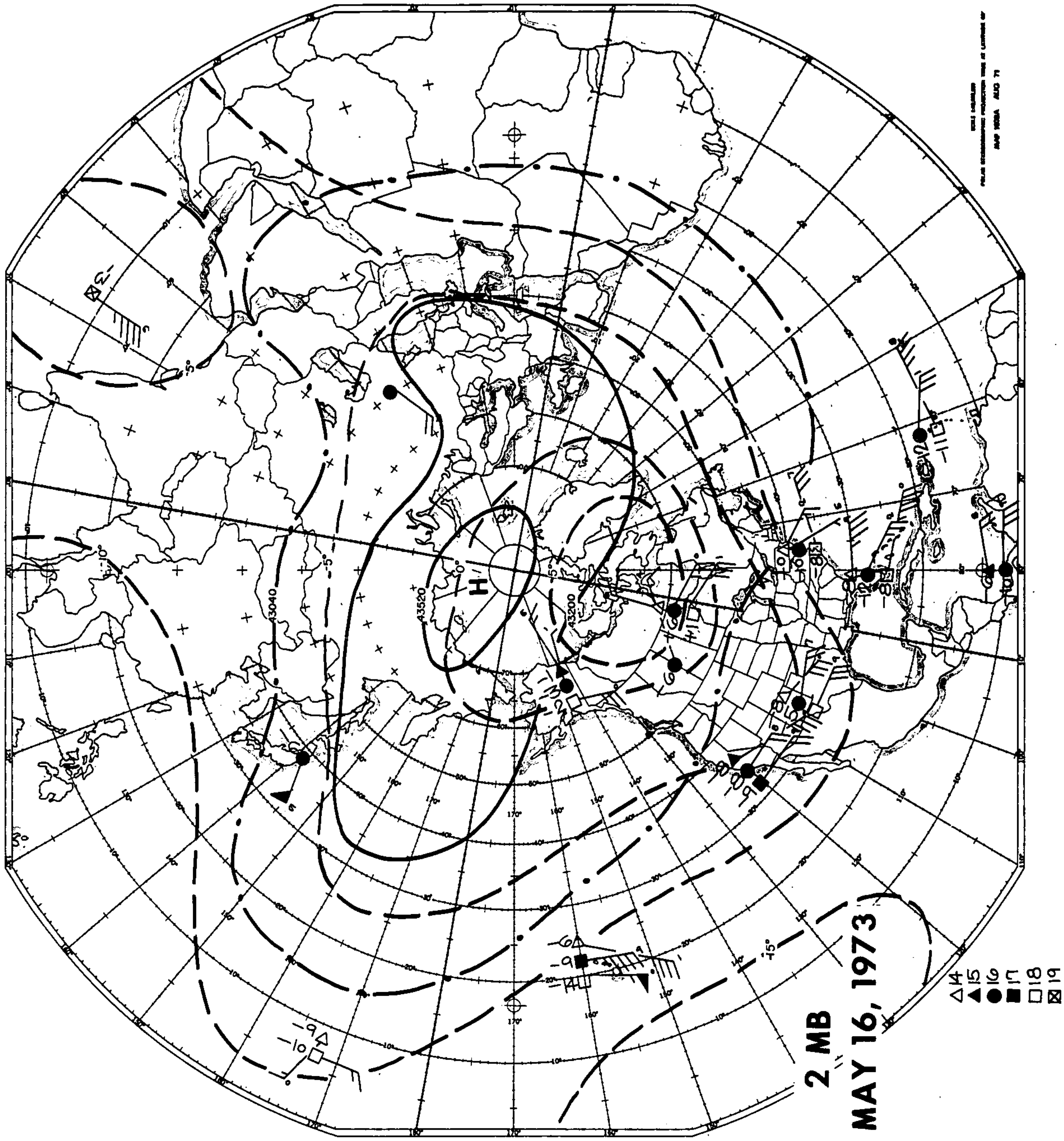
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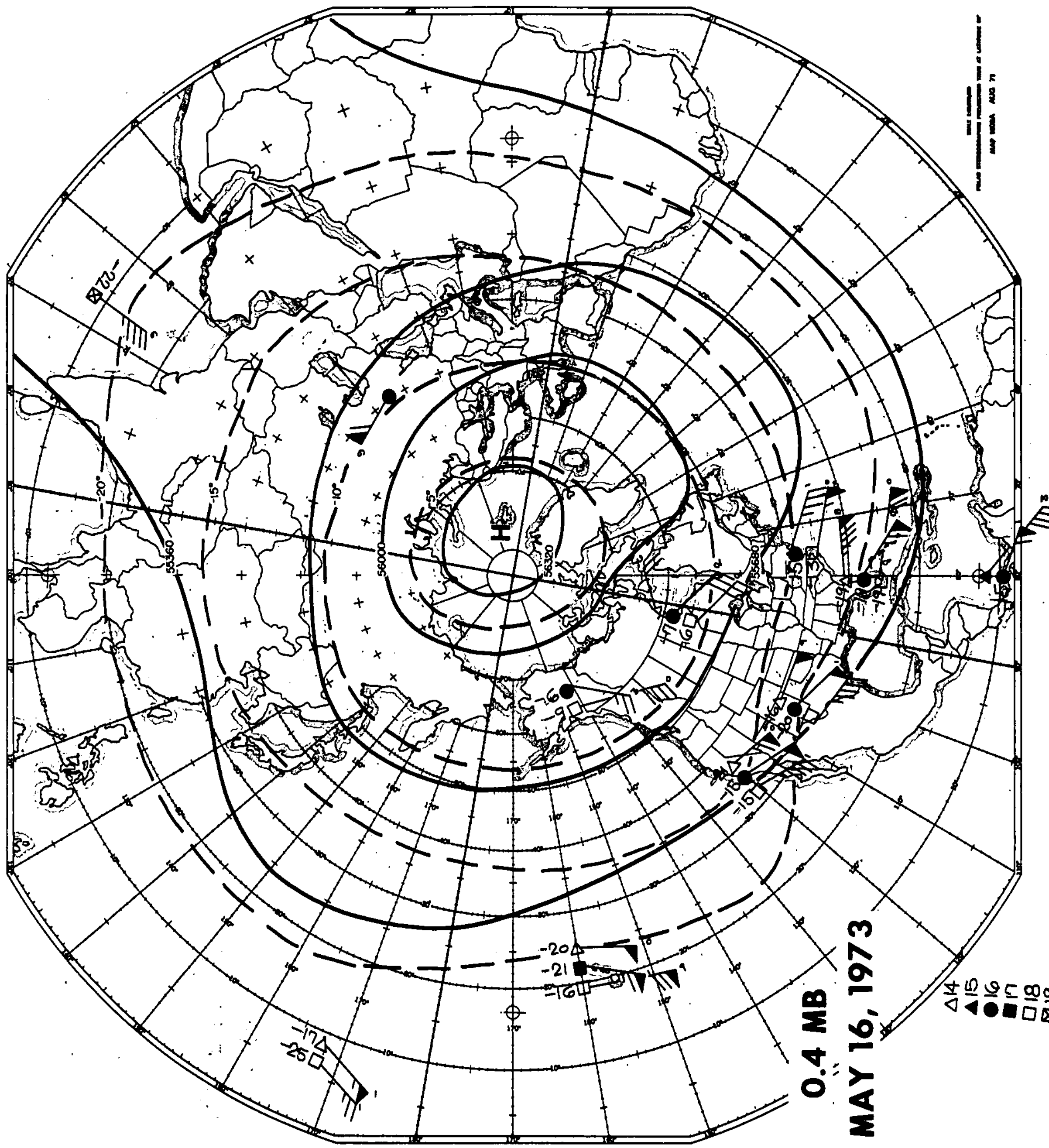
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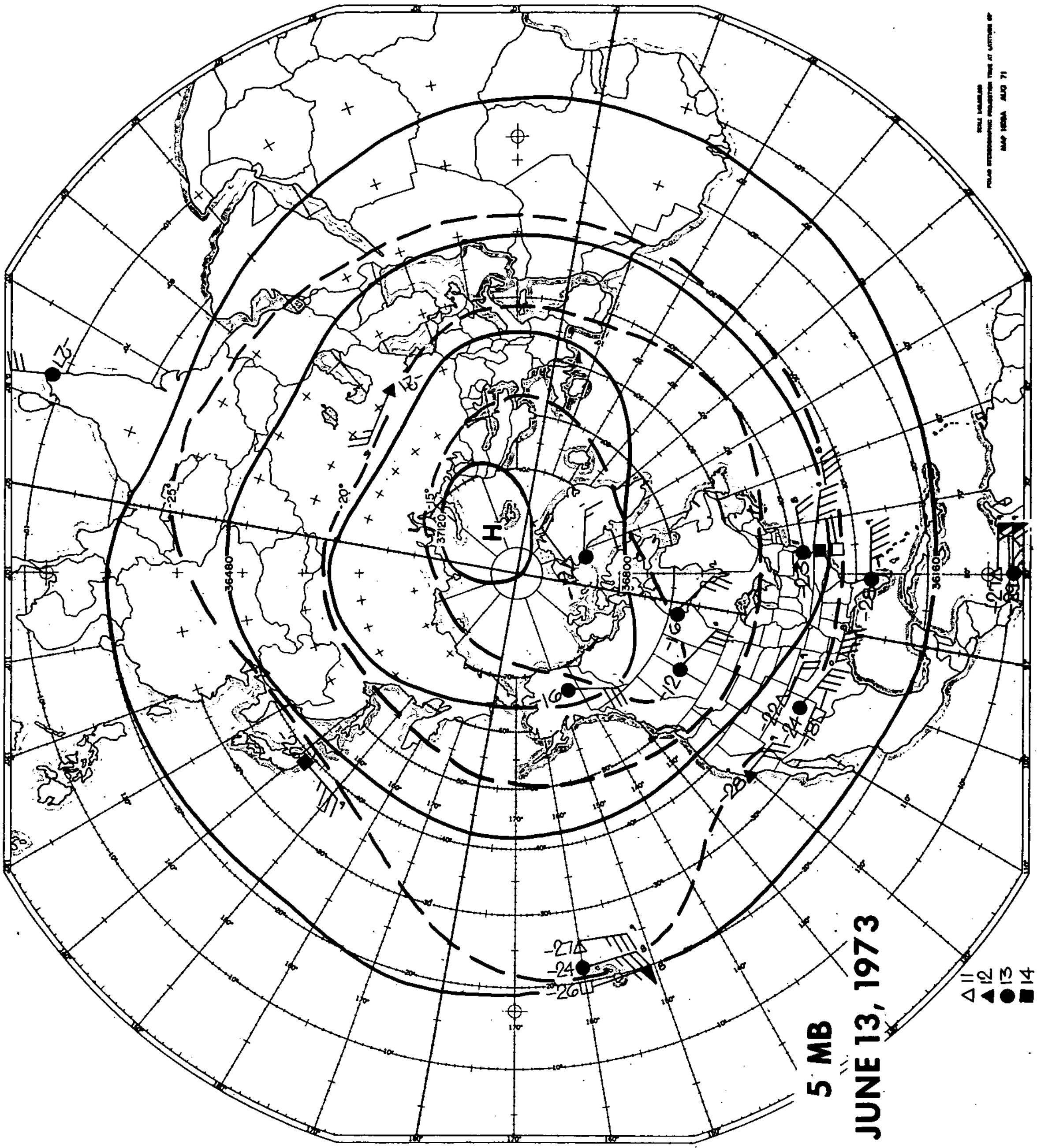
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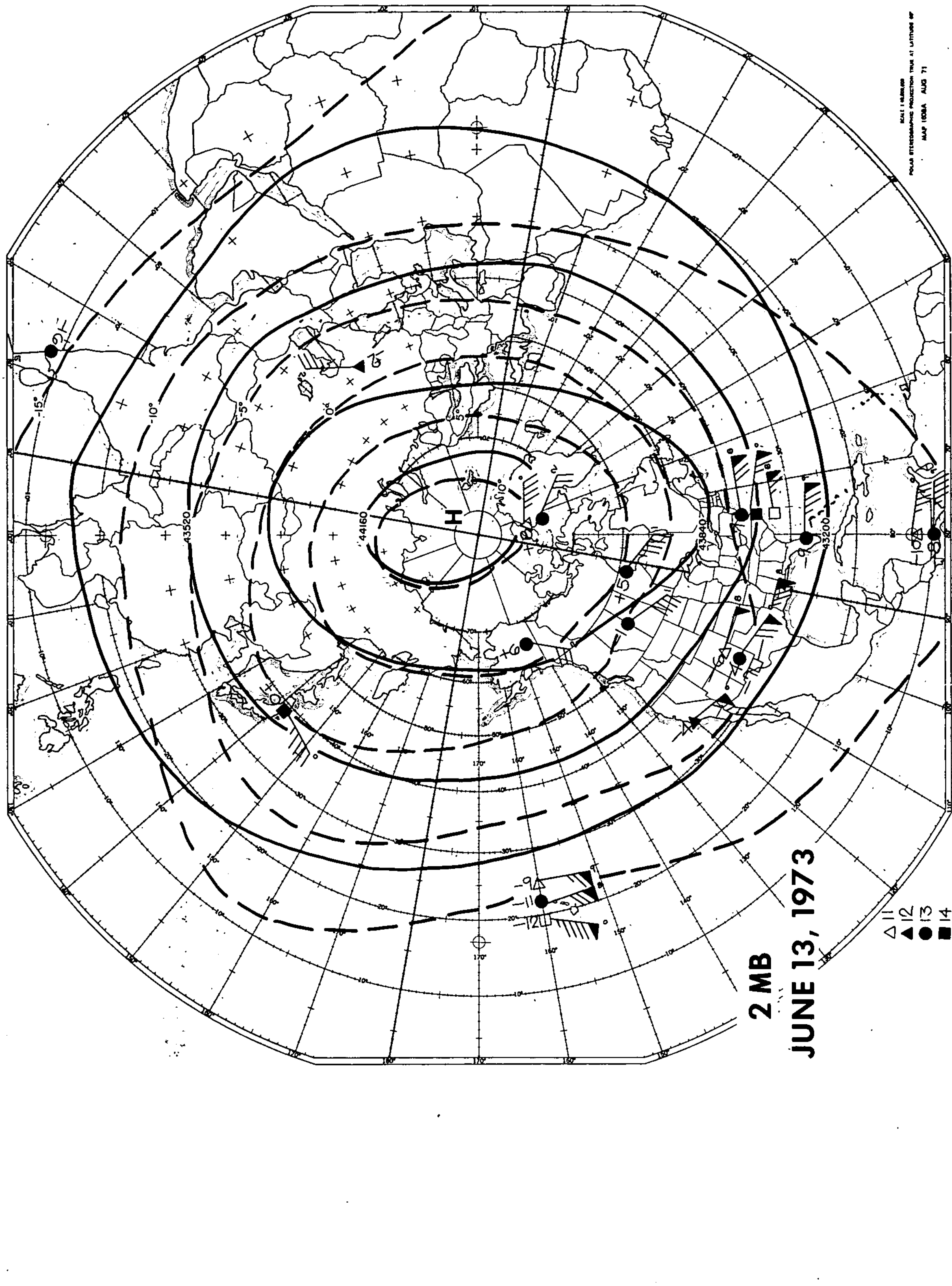
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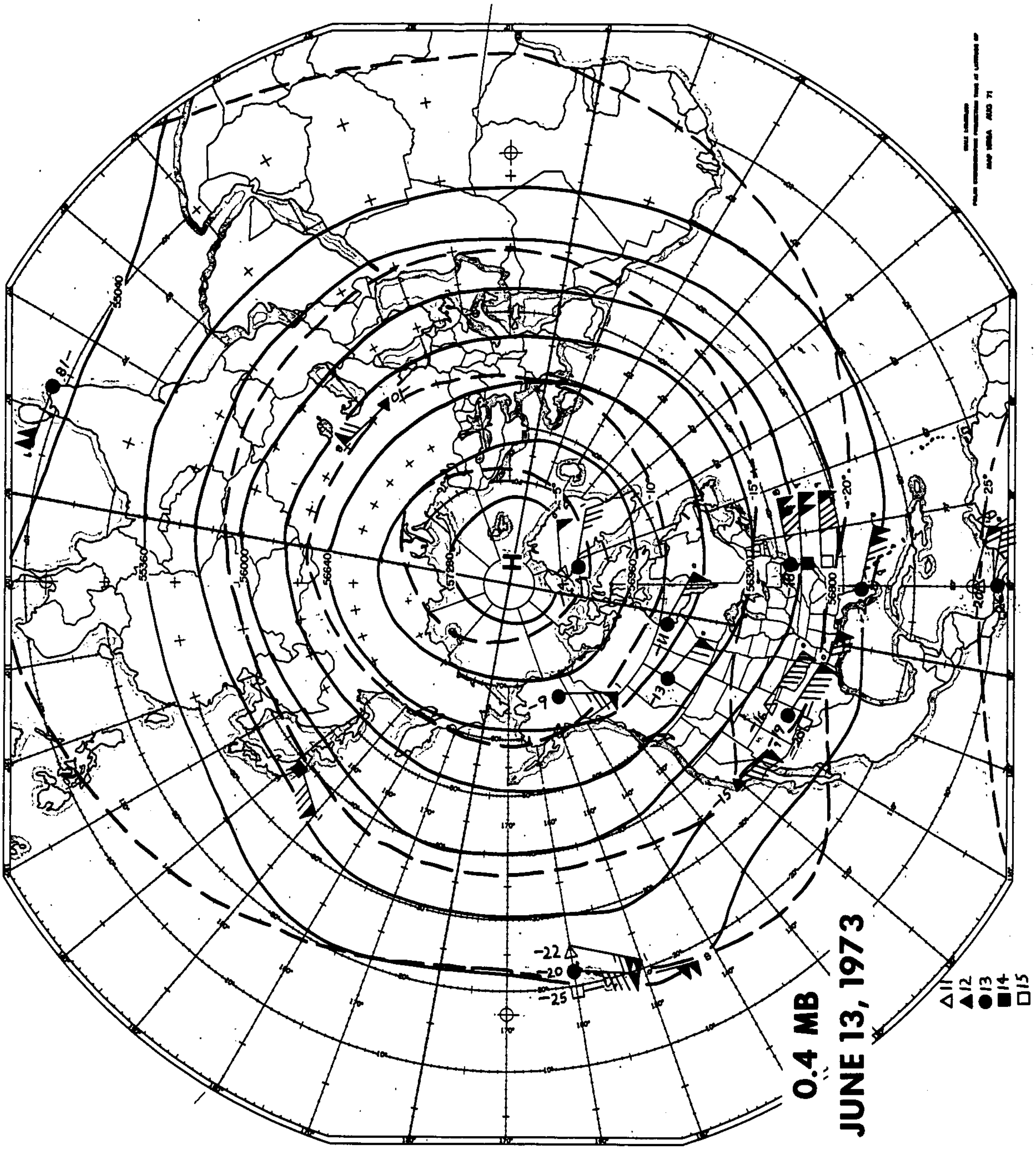

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